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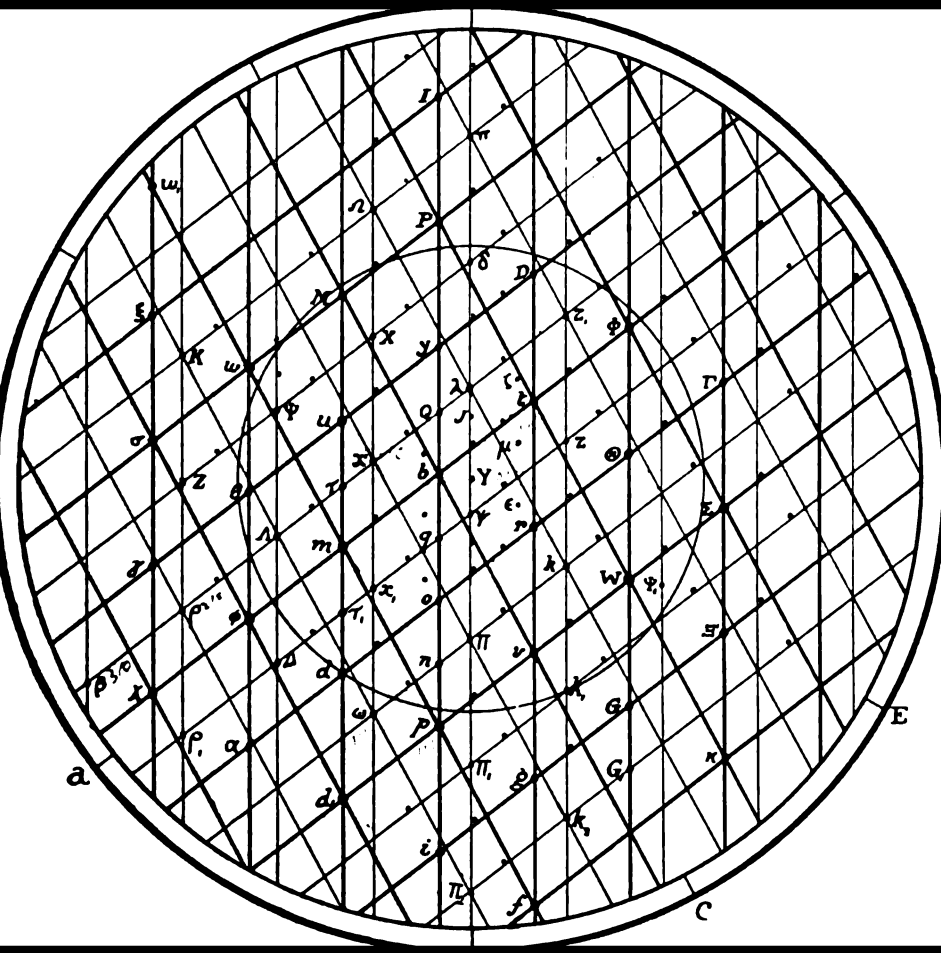

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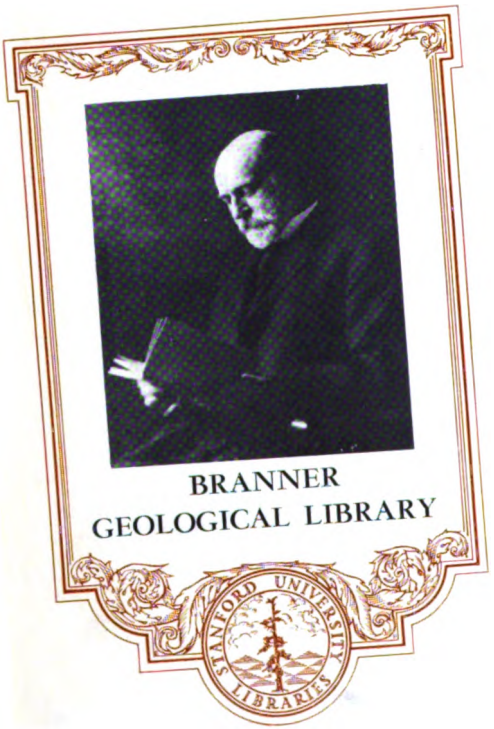

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THE

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AND

JOURNAL

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MINERALOGICAL SOCIETY

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THE MINERALOGICAL MAGAZINE

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No. 59. MAY, 1901. Vol. XIII.

On the Meteoric Stones which fell near Zomba, British Central Africa, on January 25th, 1899; with notes on the chemical analysis of such bodies. [With a map of the District, Plate I].

By L. Fletcher, M.A., F.R.S.,

Keeper of Minerals in the British Museum.

[Read, in sections, on June 20th, 1899, April 3rd, 1900, and June 19th, 1900, respectively.]

Part I.—The Circumstances of the Fall of the Stones.

ON January 25th, 1899, at 7.54 a.m., a loud noise as of an explosion was heard at the settlement of Zomba, British Central Africa, and for many miles around; almost simultaneously therewith, several small stones were seen to reach the earth in the neighbourhood of Zomba and were collected by the observers of their fall.

Mr. Alfred Sharpe, C.B., His Majesty's Commissioner and Consul-General for the Protectorate of British Central Africa, Mr. J. F. Cunningham, Secretary to the Administration, and Mr. J. McClounie, the Acting Collector of Revenues, on hearing the detonation, surmised that it had an origin in the entry of a meteorite into the earth's atmosphere, and with praiseworthy zeal and energy at once proceeded to collect, by aid of the telegraph and by personal interviews with the witnesses, all the reliable evidence that could be obtained relative to so extraordinary a

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phenomenon. A Report, embodying this information and the notes made by Mr. Cunningham and Mr. McClounie, was sent by Mr. Sharpe to the British Museum; four of the stones, generously presented by Mr. Sharpe, Mr. Cunningham and Mr. McClounie, were forwarded at the same time for scientific examination and for subsequent preservation in the Meteorite Collection of the Museum.

The details given in the Report may be classified as follows:—

Luminous Meteor and Trail.

[*Zomba.*] "There being much cloud at the time, nothing was visible to indicate that a meteorite had entered the earth's atmosphere."

[*Blantyre.*] "A native named Bwanali, who was sitting in the open near the Government buildings, saw, a little before 8 a.m., a star of exceptional brilliancy pass across the sky in the direction of Lake Shirwa (roughly, west to east)." "A native capitao in the employment of Mr. James Lindsay makes a similar statement, and adds—it left a trail or tail behind it."

[*Chiromo.*] "Mr. H. C. McDonald telegraphed that several natives saw the star and smoke. They stated that it appeared to pass over Cholo."

[*Fort Johnston.*] "Mr. O. C. Ockenden, the Acting British Vice-Consul, telegraphed that the meteorite had been seen from Fort Johnston."

[*Chengali's village.*] "Sergeant-Major Bandawe, of the British Central Africa Rifles, who was on his way to Zomba, saw the meteor when he was at Chengali's village to the west of Lake Pamalombe. It left a trail, and exploded in the direction of Chikala."

Owing to the cloudy state of the sky the luminous meteor was thus seen from only a small number of places, and presumably for only small portions of its path. It must have been far above the clouds, for it was seen from places 130 miles apart. The meteor appears to have been travelling in an approximately easterly direction, and was seen to explode when near a line drawn from Lake Pamalombe to Chikala.

Detonation.

(*a*). *Places at which it was heard.*

[*Top of Mt. Zomba.*] Mr. Sharpe says:—"I heard one very loud report."

[*Zomba.*] Mr. Cunningham says:—"There was heard a crash like thunder."

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[*Blantyre.*] "The native Bwanali heard an explosion like a crash of thunder. A native capitao in the employment of Mr. James Lindsay makes a similar statement."

[*Chikwawa.*] "Mr. J. O. Bowhill, the Judicial Officer at Chikwawa, heard the explosion as he was standing near his house. It seemed to him to come from the direction of Blantyre."

[*Katunga.*] "Mr. C. B. Vertue, the Agent of the African Lakes Company, made inquiries, and states that the explosion was heard by Muri (a native servant), 'James' and Mgano (capitaos), Njeresa and Mpeni (natives in charge of cattle).

"A native from Katunga's village came in to Chikwawa and told the Collector of Revenues that the explosion had been heard in that village."

[*Chiromo.*] "Mr. H. C. McDonald telegraphed that several natives heard the explosion."

[*Fort Johnston.*] "Mr. O. C. Ockenden telegraphed that the explosion had been heard at Fort Johnston."

As far as could be ascertained, neither the luminous meteor nor the detonation had been remarked by any one at Kota-Kota, Nkata or Karonga, places which are north of Fort Johnston and lie on the western shore of Lake Nyasa; they are in telegraphic connection with Zomba.

(*b*). *Character of the Detonation.*

The character of the detonation as heard by an observer would vary to some extent according to his situation.

[*Zomba.*] Mr. J. F. Cunningham says:—"I heard a crash like thunder, the reverberations lasting for a few minutes afterwards. When I heard it, I suspected what it was, but thought it might possibly be a dynamite explosion on the road to the new Residency, where I knew the Road-Engineer, Mr. William Fletcher, and a party of men were at work. I sent an inquiry to Mr. Fletcher, and he sent back word that he also had heard the explosion, but that it had not occurred on the Road."

Mr. J. McClounie says:—"The loud report had the precision of a cannon. I was indoors at the time, but instantly rushed out to see what had happened. My attention was drawn towards the east by the continuous rolling noise. The natives also were looking in an easterly direction."

[*Top of Mount Zomba.*] This mountain rises to a height of 6,000 feet above the sea, and is on the western side of the settlement, which is

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itself 2,900 feet above the sea. Mr. Sharpe says:—"I heard one very loud report; then for some two minutes a long rumbling or buzzing noise, gradually getting fainter and fainter; I should not call it reverberations."

[*Kuntamba's village.*] "The chief Kuntamba, at his village about three miles from the Residency, to the west of the road to Domasi, heard a noise like thunder."

[*Blantyre.*] "The native Bwanali heard an explosion like a crash of thunder."

The detonation was thus a single one; at Blantyre and about 50 miles away in the villages north-east of Zomba it was as loud as thunder: it was heard also at Chiromo, about 90 miles south of the settlement of Zomba, and also beyond Fort Johnston, which is at a distance of 70 miles to the north of Zomba; to the observers at Zomba itself the sound seemed to come from the east.

Fall of Stones.

About an hour after the detonation had been heard, news reached the Residency that several stones had fallen in native villages on the eastern slopes of Mount Zomba. As many as ten were ascertained to have been found, and these have been preserved: only those stones were discovered which fell near to people or houses, and possibly they form only a small proportion of those which actually reached the earth.

The following is the history of the individual stones:—

Stone No. 1. Weight 2 oz. (57 grams). Fell at Kuntamba's village, about three miles from the Residency, to the west of the road going to Domasi. The chief Kuntamba gave the following account to Mr. Cunningham:—"This morning I was standing near my house when I heard something fall on the rock there" (pointing to a fairly level slab of granite, measuring 20 feet by 12 feet, near his house). "Immediately after, I heard a noise like thunder. I went to the rock and saw where a stone had fallen, and I picked up some small bits."

Mr. Cunningham adds:—"There was a large crowd of the village people present when the chief told me this, and two of them, Matendu and Laici, personally vouched for its accuracy. The fragment has only a small portion of outer crust. It is the largest of the pieces found at this spot."

Stone No. 2. Weight 4½ ozs. (128 grams). Fell at Kumpamba's village, 3 miles from the Residency along the Domasi road. The fall was witnessed by the chief and others. It is the smallest of the completely encrusted stones.

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Stone No. 3. Weight 1 lb. 3 ozs. (539 grams). It was seen by a native to fall on the outskirts of the last-mentioned village. It is incomplete, a large piece having been broken off through impact against a stone when it fell. Presented to the British Museum by Mr. McClounie.

Stone No. 4. Weight 3 lbs. 5 ozs. (1502 grams). Fell on the border of a new garden on the verge of the forest about 400 yards to the south of the Likangala River, near Chiropa's village. A native was hoeing in the garden when the stone fell. The place was stony, and a corner of the meteoric stone was chipped off by the fall.

Stone No. 5. Weight 12½ ozs. (354 grams). Fell at Kampunga's village on Buchanan's Estate. "It was about noon when we (Mr. Ravenor and Mr. Cox) got to Kampunga's village (to inquire about the stone reported by Mr. Cunningham to have fallen there). We found the village people squatting round the stone in a circle, discussing the 'miracle' as they called it. No one had touched or approached the stone, and when we arrived it was still lying where it had fallen. The story of its advent was given as follows:—'A woman was pounding corn under a tree, within about ten yards of her hut, when the stone fell. The whole village heard the detonation immediately afterwards, and gathered to where the woman was standing to view the stone. They were afraid of it, thinking it enchanted, and they sat at a distance round it, each giving a version of its probable origin and meaning.' It fell on hard ground, but, as there were no rocks about, I (Mr. Ravenor) was able to dig it up complete. It is covered with crust."

Stone No. 6. Weight 5 lbs. 12½ ozs. (2622 grams). Fell to the south of the Likangala River, to the west of Stone No. 4. It is the largest stone found, is completely encrusted, and has the usual pittings.

Stone No. 7. Weight 1 lb. 13 ozs. (822 grams). Fell at Chope's village, near Songani. It is probably only part of the fallen stone, for one large surface is not encrusted. Presented by Mr. Cunningham to the British Museum.

Stone No. 8. Weight 1 lb. 6¼ ozs. (638 grams). Fell at Chirunga's village, two miles from the Residency, near the Domasi road. The side shown by a photograph of the stone is completely covered with crust.

Stones Nos. 9 and 10. Weights 14½ ozs. (411 grams) and 1 lb. 1 oz. (482 grams), respectively. Both of them fell at Kanyama's village,

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and have been presented by Mr. Sharpe to the British Museum; they are almost completely encrusted stones. "Several people heard them crashing through the trees, and after a search found first one stone and, later on, the other."

Mr. McClounie says that one small stone in its fall cut a twig from the branch of a tree; this was two miles from Zomba, off the Liwonde road; several of the other pieces were picked up at or near this place.

As the meteorite travelled in a more or less easterly direction and reached the ground only a short distance from Zomba (Plate I), and the detonation seemed to the observers at Zomba itself to come from the East, it follows that the detonation is really a consequence of the break-up of the meteorite, and not, as has been sometimes suggested, due to the rush of air into the vacuum left behind the meteorite during its flight.

Area of Distribution of the Stones.

Mr. McClounie says:—"As far as I know at present the area over which stones have fallen is about 9 miles long and 3 miles wide. Whether any fell outside this area may never be known." [The positions of the stones as indicated in the map, Plate I, must be only approximate].

The dimensions thus assigned by Mr. McClounie are exactly identical with those of the area over which the stones were distributed in the case of the meteoritic fall at Knyahinya, Hungary, on 9th June, 1866. The area of distribution of the stones, in the case of a meteoritic shower, has rarely been found to measure more than ten miles by three.

The two heaviest stones, Nos. 6 and 4, weighing respectively 5 lbs. 12½ ozs. and 3 lbs. 5 ozs., were found at the southern end of this area. The next largest, No. 7, still weighing 1 lb. 13 ozs., and probably not more than half of the stone which fell, was at the northern end of the area, and not far from the smallest completely encrusted stone, No. 2, weighing 4½ ozs.; the complete stone, No. 7, may have really been the largest which fell. Stones Nos. 9 and 10, weighing respectively 14½ ozs. and 1 lb. 1 oz., were also found north of the smallest stone.

The area of distribution on the earth's surface of the stones of a large meteoritic shower is usually, not always, elongated in the direction of flight of the luminous meteor, and the stones are generally distributed within this area approximately according to size, the larger ones being near the end towards which the meteor's flight was directed. A distribution precisely according to size would be a necessary result of the resistance of the air on the individuals of an at first closely packed swarm of similar meteoric stones moving through the earth's atmosphere in a

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direction inclined to the vertical, if each stone remain unbroken during its flight. But an admixture of sizes may result in various ways. For instance, a stone may be broken up into scattered unequal fragments at a point in its passage through the atmosphere such that the subsequent path of the fragments is not long enough for the differentiating effect of the resistance of the air to render of no moment their initial scattering in various directions.

Having regard to such considerations, it will be seen that the number of stones found at Zomba is too small and the sizes are too intermingled to admit of any sound inference as to the direction of the meteor's path from a mere study of the distribution of the fallen material, but the distribution, especially if No. 7 was really the largest stone, is not inconsistent with the direction suggested by the observations already referred to. It seems likely that the stones resulted from the breaking up of a single mass within the earth's atmosphere: there was only one detonation, and presumably only one important epoch of fracture; as the stones are completely encrusted, the scattering of the fragments must have taken place at a point where their velocity was high enough to cause superficial heating to a high temperature. As there is no mention, in the Report, of deep penetration of the ground, it is probable that the velocity was comparatively small at the time of impact on the earth's surface.

Material of the Stones.

It may be added that the material of the stones was observed to be unlike that of any of the rocks of the district, and that the specific gravity of two of the stones was determined by Mr. T. J. Binnie, Acting Chief Surveyor, to be 3·5, which is much higher than that of any of the Zomba rocks; further, Mr. McClounie noticed the numerous metallic particles glittering on the fractured surface, and proved that the material has a directive action on a compass-needle.

Part II.—The Characters of the Stones.

The Crust.

The crust is brownish-black to black in colour; it is mostly smooth, but in parts is scoriaceous or wrinkled; it shows occasional protuberances. The crust is dull, but a spot, 7 mm. in diameter, on Stone No. 7 is lustrous: in the case of Stone No. 8 a patch of crust, 8 mm. by 4 mm., is transparent and of a light green colour. On Stone No. 7 there is a linear ridge which can be traced round one of the edges of the stone for a

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distance of 70 mm.; a fracture of the crust shows that the ridge is the prolongation of a black vein in the stone. The thickness of the crust averages 0·5 mm. and reaches a maximum of 1 mm.

Each of the stones Nos. 9 and 10 has one side different in aspect from the others; instead of being comparatively uniform in curvature, this side is covered with pit-like depressions.

The Fractured Surfaces.

The fractured surface of Stone No. 7 shows part of a broken troilite-nodule, 5 mm. wide, of irregular form; an unbroken chondrule, 2 mm. in diameter, projects above the general surface; in one part is a material of vitreous lustre, curved, nearly linear and 2 mm. long.

A freshly-made fracture of Stone No. 8 varies in parts from white to whitish-grey in colour: one portion shows a dark grey oval patch, 12 mm. by 7 mm.; another was found to break through a beautifully regular bluish or bluish-grey chondrule, $2\frac{1}{2}$ mm. in diameter.

Specific Gravity.

The specific gravity was determined for a fragment, weighing 13·8522 grams, of Stone No. 8: the fragment was free from crust and exactly similar in aspect to a fragment of the same stone used for chemical analysis. The loss of weight in distilled water at 20·2° C. was 3·8973; the air was extracted from the pores by the air-pump. Duly corrected, the weight of one cubic centimeter at 20·2° C. is 3·545 grams.

Microscopic Examination.

Thin sections prepared for the microscope, when examined with the unassisted eye by reflected light, show small, very irregularly shaped, lustrous, metallic constituents (nickel-iron), and also still smaller dull opaque black particles (completely enclosed nickel-iron, troilite or chromite), dispersed through a greyish-white stony material: one of the five sections shows part of a black vein. By ordinary transmitted light the stony material is seen, with the aid of the microscope, to consist almost wholly of a nearly colourless crystalline groundmass, constituted of crystals which are chiefly small and rarely show any boundary due to the section of a natural face. Between crossed Nicols the groundmass (olivine, enstatite and plagioclastic felspar) is seen as a bright small-grained mosaic (grey, yellow, red, blue and green) interspersed with small and large crystals (the latter chiefly olivine); here and there, small quantities of a mineral nearly or quite free from cracks and polarising in grey tints (probably plagioclastic felspar) fill up intervening irregular

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spaces and mould the other crystallised material: the general aspect being very like that of sections of the meteorites of Linn County, Grossliebenthal, Girgenti and Alfianello. Enclosed in the groundmass, and intimately connected therewith, are some chondrules, few in number and almost all of them white. One of them is perfectly round and has a well marked shell, the whole of the kernel and the shell extinguishing the light simultaneously (monosomatically) and being constituted apparently of short blocks, characters which are very common in olivine-chondrules: further, as is not unusual, particles of nickel-iron are closely grouped round the greater part of the outer boundary of the shell. A second chondrule is very similar, but no shell is evident and the block-structure is less marked. A third chondrule, almost monosomatic, shows a triple shell. Other chondrules are polysomatic, being composed of several crystals having different optic orientations. In each of two slides is a section of a chondrule which, looked at with the unassisted eye, is black by reflected light; with the microscope and crossed Nicols, it is seen to consist of a transparent substance polarising in grey tints (probably plagioclastic felspar) and enclosing opaque particles which are densely packed in the centre and are almost absent near the circumference of the chondrule: a similar black chondrule is shown by a section of the Grossliebenthal meteorite. Some patches of material seen in the sections are micro-crystalline aggregates and are possibly enstatite.

Chemical Examination.

As there is necessarily more or less speculation in the interpretation of the results observed during the chemical examination of a mechanical mixture of compounds having one or more chemical elements in common, the observations and calculations are conveniently kept quite distinct from each other and recorded in separate sections. Both are given in detail, so that future investigators of meteoric stones may know the kind of difficulty which presents itself in such an inquiry, and may form an estimate of the weight to be assigned to the numerical results arrived at.

Section I. Observations.

WEIGHTS OBTAINED IN THE COURSE OF THE CHEMICAL ANALYSIS.

Magnetic Separation.

1. A freshly broken, easily frangible, crustless fragment of Stone No. 8, weighing 14·6 grams, was crushed in a steel mortar, and afterwards pulverised, in small portions at a time, in an agate mortar; it was impossible, owing to the presence of malleable grains of nickel-iron alloy,

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to reduce the material in this way to a fine powder of uniform composition. The alloy was next magnetically extracted by means of a seven-toothed iron comb, such as is used by grainers, but which had been magnetised: the powder being worked through in small quantities at a time. The residual powder was again pulverised in the agate mortar and the magnetic separation repeated. At the end of a series of operations the material had been divided into two parts; the one, attracted, weighing 2·0144 grams; the other, unattracted, weighing 12·4208 grams; the total quantity of material available for analysis being thus 14·4352 grams. The attracted material consisted of particles of different sizes; some of them were about a millimeter in diameter; much of the remainder consisted of smaller but still coarse grains, and another portion consisted of particles which were extremely minute and thus readily oxidisable on exposure to air or moisture: the unattracted material was an impalpable powder of a bluish-grey colour and apparently quite free from iron-rust.

ATTRACTED MATERIAL: TOTAL WEIGHT 2·0144 GRAMS.

Treatment with solution of mercuric ammonium chloride.

2. 0·7421 gram of the attracted material was transferred to a small flask and treated with cold mercuric solution in an atmosphere of hydrogen as described in a previous paper,[1] the flask and contents being frequently shaken during the daytime; after the action had proceeded for some time, the liquid was quickly filtered, and the insoluble matter was washed with cold water which contained a little mercuric solution and had been boiled to expel dissolved air. For each of the first two extractions 200 cc. of the mercuric solution were used; for each of the next five, 100 cc.: the first extraction was allowed to proceed for 8 hours; each of the next four, for 24 hours; the sixth, for 96 hours; and the seventh, for 24 hours.

Each of the extracts was acidified, heated to boiling, and precipitated by sulphuretted hydrogen, and the several filtrates were evaporated to dryness. The residue from the third extract showed by its colour that an appreciable amount of alloy had been extracted by the mercuric solution, and there was still an evident tinge of colour even in the residue from the seventh extract; the coloration was much smaller in the case of the fourth and fifth extracts than in that of the third, while those of the sixth and seventh, though evident, were only just appreciable; the last

[1] Mineralogical Magazine, 1894, vol. 10, p. 293.

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two were of about equal intensity although the sixth extraction had occupied four days and the seventh only one. There was by this time much admixed mercury and mercurous chloride, protecting the material to some extent from the action of the solvent; possibly, also, some of the particles of the alloy were so large as to require a very prolonged action to produce solution; possibly some had been superficially oxidised and were partially sheltered by the oxide from contact with the liquid: undissolved particles of alloy are very liable to be superficially oxidised when exposed to the air during the filtration. The extraction, although incomplete, was accordingly not further proceeded with at this stage.

The various precipitates produced by the sulphuretted hydrogen were ignited and the mercury driven off; there remained a small brownish residue, which was soluble in warm hydrochloric acid, and gave a rich yellow solution; it was again precipitated by sulphuretted hydrogen, and the filtrate, which may contain a little iron carried down by the mercuric sulphide, was added to the main extracts. The brown precipitate weighed after ignition 0·0001 gram, and was found to be due to the presence of copper. The extracts having been collected together, the iron was oxidised, and at the same time the ammonium chloride decomposed, by evaporation with strong nitric acid; the residue was then treated with strong hydrochloric acid and again evaporated to dryness. From the dilute solution the iron was separated from the nickel by a fourfold precipitation with sodium acetate; probably two precipitations would have sufficed, for it was afterwards found that the nickel separated by the third and fourth precipitations was scarcely large enough to be appreciable. After a final precipitation with ammonia and ignition, the precipitate weighed 0·4933 gram. Of this, 0·4054 gram was ignited in a current of hydrogen and treated with hydrochloric acid; the insoluble SiO_2 weighed 0·0028, and was probably due to the action of the voluminous boiling liquid on the glass during the four precipitations of the iron. The dissolved iron was precipitated by ammonium sulphide, and the filtrate, which showed no trace of nickel (thus indicating the completeness of the separation from that metal), was evaporated to dryness; the ammoniacal salt was expelled by gentle ignition: from the residue then obtained, a small quantity of phosphorus (presumably due to oxidation of schreibersite, phosphide of iron and nickel) was eventually separated by molybdic solution and afterwards by magnesia mixture: the $Mg_2P_2O_7$ weighed only 0·0005.

The nickel and cobalt were twice precipitated by caustic potash and bromine water; as oxides they weighed 0·0606, as metal 0·0487. The

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cobalt was separated from the nickel by the nitrite method and converted into potassium cobalt sulphate ($3K_2SO_4 \cdot 2CoSO_4$); this weighed 0·0166.

3. The residue from the action of the mercuric solution was in two parts: one part, still adherent to the filter, weighed after ignition (and therefore partial oxidation) 0·0019 gram; the other part, which had been washed from the filter, contained some bright metallic spangles (probably schreibersite, phosphide of iron and nickel) mingled with much mercurous chloride, mercury and coarse grains of silicate; further, much of the material was found to be still magnetic; after being heated in a current of hydrogen to a temperature just below visible red heat until no further volatilisation took place, it weighed 0·3366 gram. The residual powder, instead of consisting of light coloured silicates, as had been expected, was almost wholly of a dull black colour, but further contained the lustrous metallic spangles already referred to; and the whole was attracted by the compass-needle, showing that the coarse grains of silicate, obviously present, themselves contained magnetic matter. It was inferred that the powder consisted largely of magnetic oxide of iron; the residue was therefore heated to low redness in a current of hydrogen, again submitted to the action of the mercuric solution, transferred back to the boat and again heated in hydrogen; as the residue was not much diminished and was still of a dull black colour, the operations were repeated, the temperature being raised to full red heat, but with a similar result. After a further extraction with mercuric solution, the residue was again heated in hydrogen to a full red heat and weighed (0·2759 gram). The part adherent to the filter weighed, after ignition, 0·0091 gram. The combined extracts yielded, after a double precipitation with sodium acetate, Fe_2O_3 0·0439 and Ni(Co) 0·0135.

4. As the total residue had only been reduced by the last operations from 0·3366 gram to 0·2850 gram and was not appreciably changed in aspect, it was decided to treat the residue with hydrochloric acid and to analyse it in the same way as the unattracted material.

0·2757 gram was treated on the waterbath with dilute HCl (s. g. 1·06); there was immediate effervescence, which lasted for ten minutes. From this it is inferred that particles of alloy had been protected from the mercuric solution by a coating of oxide or by enclosure in grains of olivinic silicate, probably in both ways. The silica set free by the acid was separated by means of sodic solution and weighed (0·0447 gram). The residue washed from the filter weighed 0·1280 and was white; the part adherent to the filter weighed, after ignition, 0·0129 gram.

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From the acid solution the following weights were obtained:—

Fe_2O_3,SiO_2 0·0450 (yielding SiO_2 0·0013, presumably due to the action on the vessels).

Ni(Co)O 0·0088; yielding Ni(Co) 0·0072.

CaO 0·0036, probably almost entirely due to the action on the glass and porcelain during the precipitation of the iron and the separation of the nickel.

$Mg_2P_2O_7$ 0·1137.

UNATTRACTED MATERIAL: TOTAL WEIGHT 12·4208 GRAMS.

Extractions with Water, Alcohol and Ether.

5. 1·0017 grams of the unattracted material were transferred to a platinum dish and covered with 100 cc. of distilled water; after being boiled the solution was allowed to cool and then filtered without prolonged standing; the filtrate was opalescent. It was evaporated to dryness, 100 cc. of water were again added, and the liquid was boiled. It was afterwards filtered, the filter being on this occasion left unwashed; the filtrate was now limpid and yet contained all the soluble matter; the powder adherent to the dish and filter was doubtless finely divided silicate which had been in a state of suspension and had caused the opalescence. The soluble residue yielded by the evaporation of the filtrate weighed 0·0026 gram, or 0·26 per cent.

Its solution was inactive to litmus and turmeric, and gave a rich yellow colour to the Bunsen flame. On spontaneous evaporation it began to deposit a precipitate as soon as it became concentrated, the liquid becoming quite milky in appearance when its volume had decreased to a cubic centimeter; after the evaporation was complete, the residue, examined with the microscope, was seen to consist mostly of small crystals optically isotropic, but of no distinct form; there were a few isolated groups of radiating birefringent plates, and also some isolated acicular crystals having straight extinction. The solution gave no precipitate with ammonia and ammonium chloride, even on boiling, but was found to contain calcium and a minute amount of magnesium. It contained sulphate in considerable quantity, but only an extremely minute trace of chloride; no phosphate could be detected. This is virtually the same result as was obtained in the examination of the Makariwa stone[1]; in that case it was inferred that the salts found in the extracting water were due to a partial oxidation of the protosulphide of iron (troilite) to

[1] Ibid. p. 297.

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sulphate, and to the subsequent action of the dissolved sulphate on the silicates, but it was uncertain whether the oxidation had taken place during the aqueous extraction itself or while the stone was lying buried in the ground. As the Zomba stone was quite fresh, it may be concluded that the oxidation of the troilite takes place during the boiling, and that the soluble salts may be accounted for without being regarded as original constituents of the meteoric stone.

The residue left after treatment with the distilled water was digested with 50 cc. of absolute alcohol for three days, and afterwards with 50 cc. of ether for 30 minutes; in neither case was anything weighable extracted.

Determination of chromite: absence of diamond.

6. The same residue was treated finally with hydrofluoric and sulphuric acids. The insoluble material was transferred to a watch-glass and microscopically examined; as it was entirely opaque and of metallic lustre, no diamond could be present; after ignition it weighed 0·0035 gram and gave the reactions of chromium. The above number corresponds to 0·35 per cent. of chromite in the unattracted material; but it is only a minimum, for part of the chromite, being very finely divided, would probably yield to the attack of the acid and be carried into solution.

Determination of sulphur and phosphorus: absence of titanium.

7. 0·9920 gram, treated in the way described in a previous paper[1], yielded $BaSO_4$ 0·1481 and $Mg_2P_2O_7$ 0·0024. During these operations, it was ascertained that titanium was absent.

Determination of the alkalies.

8. 0·4815 gram, analysed by the Lawrence Smith method, gave:—Sodium and potassium chlorides 0·0135; tested with a small spectroscope only the sodium line was visible: K_2PtCl_6 (free from filter) 0·0040; adherent to filter and ignited, 0·0036.

A blank experiment simultaneously made with the same reagents gave:—Sodium and potassium chlorides, 0·0021: K_2PtCl_6 (free from filter) 0·0056; adherent to filter and ignited, 0·0012.

Treatment with mercuric solution.

9. 4·9856 grams were treated with mercuric solution in an atmosphere of hydrogen, as already described; the extraction proceeded for 24 hours and was performed three times. The first extract was appreciable; the second and third showed only slight tinges of colour.

[1] Ibid. p. 298.

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The combined extracts yielded :—

CuS (ignited in air) 0·0003.

After oxidation of the iron and decomposition of the ammonium chloride, the residue was green, showing its comparative richness in nickel : the solution gave

Fe_2O_3,SiO_2 0·0025, yielding SiO_2 0·0004.

NiO 0·0007.

CaO 0·0040, probably almost entirely due to the action on the glass and porcelain during the precipitation of the iron and the removal of the nickel.

$Mg_2P_2O_7$ 0·0037.

Treatment with hydrochloric acid and sodic solution : First Portion.

10. 2·5065 grams of that part of the unattracted material which had not been subjected to the action of the mercuric solution were extracted three times with dilute hydrochloric acid, according to the method described in a previous paper.[1] In this case the extracts were decanted from the undecomposed material (admixed with free silica), and the decanted liquid and the undecomposed material separately evaporated to complete dryness ; the continued action of the acid on the main material during the evaporation was thus prevented, though a certain amount of action on the finely divided silicate suspended in the liquid cannot be avoided. The free silica was next extracted with strong solution of sodium carbonate (to which a piece of caustic soda had been added) ; in the last stages of the washing of the undecomposed material a little of the finely divided silicate passes through the pores of the filter ; the amount of this was afterwards determined. The sodic extract was examined, not only for silica, but for bases.

The following numbers were obtained :—

a. Undecomposed material : part washed from filter, 0·9186 ; part adherent to filter and ignited, 0·1328.

b. The acid solution yielded : —

Fe_2O_3,Al_2O_3,SiO_2 0·4639 ; of this 0·4150, after the iron had been expelled by the Deville-Cooke method, gave Al_2O_3,SiO_2 0·0055, and from this 0·0019 of SiO_2 was obtained.

MnS 0·0068.

NiO 0·0001.

The rest of the acid solution, containing the calcium and magnesium, was lost.

[1] Ibid. p. 302.

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c. The sodic solution yielded :—

SiO_2, with trace of undecomposed material, 0·4909. After treatment with HF and H_2SO_4 and subsequent ignition, 0·0039. The residue thus obtained was partly reddish and partly white ; the former was oxide of iron, the latter was found to contain magnesium ; the residue was thus due to the trace of undecomposed material which had passed through the pores of the filter.

Fe_2O_3,Al_2O_3,SiO_2 0·0048, yielding SiO_2 0·0031 and the Fe_2O_3, as judged from the colour, being small.

CaO 0·0020, partly due to action on the vessels.

Treatment with hydrochloric acid and sodic solution : Second Portion.

11. 2·7333 grams of the unattracted material, which had been subjected to the action of the mercuric solution (§ 9) and still contained mercury and mercurous chloride, treated in the above way with hydrochloric acid, gave the following :—

a. Undecomposed material : part washed from filter, 1·0981 ; part adherent to filter and ignited, 0·0516.

b. The acid solution yielded :—

Fe_2O_3,Al_2O_3,SiO_2 0·5013 ; of this 0·4169 gave Al_2O_3,SiO_2 0·0044, which yielded SiO_2 0·0028.

MnS 0·0074.

NiS (after ignition in air) 0·0012.

(CaO, due to action on the vessels, 0·0022.)

CaO 0·0105 (in all the analyses the calcium was twice precipitated).

SiO_2 0·0061 was obtained after the decomposition of the ammonium chloride by nitric acid, and is a measure of the amount of action on the vessels.

$Mg_2P_2O_7$ 1·3834.

c. The sodic solution yielded :—

SiO_2, with trace of undecomposed material, 0·5301.

After treatment with HF and H_2SO_4 and subsequent ignition, 0·0017.

Fe_2O_3,Al_2O_3,SiO_2 0·0065 ; of this 0·0046 gave Al_2O_3,SiO_2 0·0032, which itself yielded SiO_2 0·0007.

CaO 0·0018 (probably due, in part at least, to the action on the glass and porcelain).

d. Another portion, weighing 2·0583 grams, lost 0·0512 of volatile material when heated, in a current of hydrogen, in a platinum boat

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contained in a platinum tube supported in an oven at 298° C.; at this low temperature the troilite remains unaffected.

Treatment with hydrochloric acid and sodic solution: Third Portion.

12. 2·0317 grams of the unattracted material, which had been subjected to the action of the mercuric solution (§ 9), but from which the volatile material had been removed by heating at a low temperature in a current of hydrogen, gave the following numbers:—

a. Undecomposed material: part washed from filter, 0·8107; part adherent to filter and ignited, 0·0241.

b. The acid solution yielded:—

Fe_2O_3,Al_2O_3,SiO_2 0·3775; of this 0·3352 gave Al_2O_3,SiO_2 0·0018, and the latter when analysed yielded Al_2O_3 0·0001, SiO_2 0·0016.

CuS (ignited in air) 0·0003.

MnS 0·0056.

Ni(Co) 0·0010.

CaO 0·0107.

SiO_2 0·0067 was obtained after the decomposition of the ammonium chloride by nitric acid, and is a measure of the amount of action on the vessels.

$Mg_2P_2O_7$ 1·0958 (and this includes the calcium and aluminium due to the action of the nitric acid on the porcelain dish).

c. The sodic solution yielded:—

SiO_2, with trace of undecomposed material, 0·4208. After treatment with HF and H_2SO_4 and subsequent ignition, 0·0026.

Fe_2O_3,Al_2O_3,SiO_2 0·0069; of this 0·0047 gave Al_2O_3,SiO_2 0·0022, and the latter when analysed gave Al_2O_3 0·0024, SiO_2 0·0001.

(CaO, due to action on porcelain dish, 0·0012).

Examination of the blank sodic solution.

13. The amount of the alumina extracted by the sodic solution being appreciable though small, and the amount of sodic solution used being large, it was desirable to make similar experiments on the sodic solution itself. Taking the same amount of sodic solution (20 grams of crystallised sodium carbonate and 2½ grams of caustic soda) as was used in the last analysis, the following numbers were obtained:—

SiO_2 0·0049.

Fe_2O_3,Al_2O_3,SiO_2 0·0009 (the alumina and silica being probably inappreciable).

CaO 0·0005.

CaO 0·0019, due to action on the porcelain dish.

$Mg_2P_2O_7$ *nil*.

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Undecomposed Material: Specific gravity.

14. The material left undecomposed by the acid and sodic solutions was white in colour, but there was admixed with it a little black material of higher specific gravity than that of the silicate; the black material was found to be chromite. The specific gravity of the admixture was determined from 1·2831 grams of the material by means of a 8 cc. pycnometer. The usual corrections for the temperature of the water and for the displaced air being made, it was found that the weight of the material which occupies a cubic centimeter at 17° C. is 3·171 grams.

Undecomposed Material: Chemical analysis.

15. 0·8981 gram of the undecomposed material was fused with mixed potassium and sodium carbonates. There was a perceptible action on the platinum crucible involving the eventual separation of a little platinum from the magnesium pyrophosphate, but otherwise not interfering with the analysis. The chromite was partially decomposed, and the chromium which passed into solution manifested itself by the green colour of the oxides after the iron had been removed from the ignited precipitate by the Deville-Cooke method; the oxides of iron, aluminium and chromium had been twice precipitated together in dilute solution by the sodium acetate method and finally with ammonia; they were thus free from magnesium.

The following numbers were obtained:—

SiO_2 + chromite 0·5056.

Chromite, after treatment with HF and H_2SO_4, 0·0027.

$Fe_2O_3, Cr_2O_3, Al_2O_3, SiO_2$ 0·1545; of this 0·1201 yielded Cr_2O_3, Al_2O_3, SiO_2 0·0393, which itself on being analysed gave Cr_2O_3 0·0054, Al_2O_3 0·0314, SiO_2 0·0006, the loss being probably Al_2O_3.

MnS 0·0042.

CaO 0·0369 (a double precipitation with ammonium oxalate).

$Mg_2P_2O_7$ 0·5384.

16. *Alkalies.* 0·4994 gram of the undecomposed material, analysed by the Lawrence Smith method, gave:— Sodium and potassium chlorides 0·0183: K_2PtCl_6 (free from filter) 0·0079; adherent to filter and ignited 0·0025. During the operation the chromite was, partially at least, converted into chromate, and Cr_2O_3 0·0018 was separated from the alkaline solution before the mixed chlorides could be weighed.

Undecomposed material: Action of hydrochloric acid and sodic solution.

17. It is well known that the residue from the treatment with hydrochloric acid and sodic solution is far from insensible to the action of

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those reagents; it became desirable to ascertain the amount of this action under similar circumstances to those of the analyses of the unattracted material itself.

1·0388 grams of the undecomposed material were therefore treated in the same way as the unattracted material. The following numbers were obtained:—

a. Residual material: part washed from filter, 0·8807; part adherent to filter and ignited, 0·0363.

b. The acid solution yielded:—

Fe_2O_3,Al_2O_3,SiO_2 0·0150; of this 0·0080 gave Al_2O_3 0·0005 and SiO_2 *nil.*

SiO_2 0·0022 was obtained from the solution, and is a measure of the action on the vessels.

CaO 0·0076.

After decomposition of the ammonium chloride by nitric acid, SiO_2 0·0033 and Fe_2O_3,Al_2O_3 0·0008 were separated from the solution, and were due to the action of the nitric acid on the porcelain dish.

$Mg_2P_2O_7$ 0·0649.

c. The sodic solution yielded:—

SiO_2, with trace of undecomposed material, 0·0763.

After treatment with HF and H_2SO_4 and subsequent ignition, 0·0014.

Fe_2O_3,Al_2O_3,SiO_2 0·0071; of this 0·0060 gave Al_2O_3,SiO_2 0·0052, and the latter when analysed gave Al_2O_3 0·0048 and SiO_2 *nil.*

CaO 0·0028.

[Further CaO 0·0016, due to action of nitric acid on the porcelain dish.]

$Mg_2P_2O_7$ *nil.*

Undecomposed material: Effect of ignition.

18. As the undecomposed material contains a considerable proportion of ferrous oxide, it was probable that ignition would appreciably increase its weight. It is necessary to determine the amount of this action, for that part of the silicate which is adherent to the filter cannot be weighed until after ignition.

0·0332 gram of the undecomposed material, after ignition with the gas blowpipe, became 0·0331; there was thus no appreciable change of weight, the increase of weight by oxidation being neutralised by loss due to volatilisation.

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Undecomposed material: Effect of hydrofluoric and sulphuric acids followed by ignition.

19. Similarly, it is necessary to determine the effect of hydrofluoric and sulphuric acids, followed by ignition, in order to determine for each case the amount of the finely divided silicate which has passed through the pores of the filter and is admixed with the silica. It was found that 0·0696 gram of the undecomposed material gave after this treatment a residue which weighed 0·0572.

Action of nitric acid on the porcelain.

20. For the precipitation of the small amount of calcium, it is necessary to add to the solution enough ammonium oxalate to convert not merely the calcium itself, but also the magnesium, into oxalate, otherwise part of the calcium may remain in solution. The large amount of ammoniacal salt thus introduced has to be removed before the precipitation of the magnesium: if this is effected by evaporation and ignition, there is great danger of loss through spurting; if it is effected by evaporation with strong nitric acid, there is an appreciable action on the porcelain dish and the magnesium precipitate is not quite pure. The amount of action depends on the duration of the evaporation with nitric acid and on the amount of the latter; it will thus vary in different experiments. To gain some idea of the amount of the action, the silica and calcium thus brought into solution were on several occasions determined and have been recorded above:—

SiO_2 0·0061 (§ 11), 0·0067 (§ 12).
CaO 0·0036 (§ 4), 0·0040 (§ 9), 0·0020 (§ 10), 0·0013 (§ 11), 0·0022 (§ 11), 0·0012 (§ 12).

The mean of the numbers for the CaO is 0·0024; the weight of the corresponding $Ca_2P_2O_7$ would be 0·0054: this amount may therefore be properly subtracted from the determined weight of the $Mg_2P_2O_7$ when the amount of nitric acid used has been about the average.

Section II. Calculations.

Interpretation of the analytical results.

Atomic Weights.

21. The atomic weights used in the following calculations are those

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recommended by Professor F. W. Clarke, in the Seventh Annual Report of the Committee on Atomic Weights[1], namely :—

Al	26·9	Fe	55·6	O	15·88
Ba	136·4	H	1	P	30·75
Ca	39·8	K	38·82	Pt	193·4
Cl	35·18	Mg	24·1	S	31·83
Co	58·55	Mn	54·6	Si	28·2
Cr	51·7	Na	22·88		
Cu	63·1	Ni	58·25		

It is convenient to make the calculations in the following order.

Undecomposed Material.

22. *Alkalies.* K_2PtCl_6 0·0079 (§ 16) corresponds to KCl 0·0024; 0·0025, adherent to the filter and ignited, if taken as Pt·2KCl, corresponds to KCl 0·0019; making altogether KCl 0·0035. From the blank experiment (§ 8), K_2PtCl_6 0·0056 and Pt·2KCl 0·0012 correspond respectively to KCl 0·0017 and KCl 0·0005; making in all 0·0022; as the direct weight of the chlorides was only 0·0021, the whole 0·0021 must have been potassium chloride. The potassium chloride due to the silicate is thus 0·0014. The mixed chlorides due to the silicate weigh 0·0188 (§ 16)—0·0021 (§ 8) or 0·0162; hence the NaCl due to the silicate is 0·0148.

These amounts of NaCl and KCl correspond respectively to Na_2O 0·0079 and K_2O 0·0009 for 0·4994 of undecomposed material, and to Na_2O 1·58, K_2O 0·18 per cent.; no stress can be laid on the number for K_2O.

As the undecomposed material had been boiled three times, each time for five minutes, in a strong sodic solution, it is not inconceivable that soda might have been introduced into its composition. But the residue had been subjected to a very long continued washing to secure the complete removal of soluble matter; further, there is already a certain amount of sodium in the mixed silicates before the digestion with sodic solution (§ 5, § 8), and a consideration of the weights of the soda in the mixed silicates and the undecomposed material suggests that the sodium is an original constituent of the latter.

23. 0·1201 (§ 15) of mixed oxides consists of Cr_2O_3 0·0054, Al_2O_3 0·0333, Fe_2O_3 0·0808 and SiO_2 0·0006; hence 0·1545 of mixed oxides

[1] Journ. Amer. Chem. Soc. 1900, vol. 22, p. 70.

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consists of Cr_2O_3 0·0070, Al_2O_3 0·0428, Fe_2O_3 0·1089 (and SiO_2 0·0008, due to the action on the glass).

Cr_2O_3 0·0070 must have been originally present as chromite ($FeO \cdot Cr_2O_3$) and requires FeO 0·0033; chromite 0·0103 has thus been decomposed further, undecomposed chromite 0·0027 was admixed with the main silica. The total chromite was therefore 0·0130.

Fe_2O_3 0·1089 corresponds to FeO 0·0935; of this 0·0033 is due to chromite, leaving 0·0902 for the silicate.

MnS 0·0042 corresponds to MnO 0·0034.

Deducting 0·0054 (§ 20) from the weight obtained for the $Mg_2P_2O_7$ 0·5384, the pure $Mg_2P_2O_7$ is 0·5330, corresponding to MgO 0·1930.

For 0·8981 of undecomposed material (§ 15), Na_2O is 0·0141 and K_2O 0·0016 (§ 22).

Hence we have the following numbers:—

		Zomba. Percentages for silicate.	Zomba. Oxygen.		Linn County. Percentages for silicate.
Chromite	0·0130	—	—		—
SiO_2	0·5029	56·83	30·10		55·08
FeO	0·0902	10·19	2·26	} 12·22	} 13·58
MnO	0·0034	0·39	0·09		
MgO	0·1930	21·81	8·68		22·70
CaO	0·0369	4·17	1·19		2·85
Al_2O_3	0·0428	4·84	2·27		4·86
K_2O	0·0016	0·18	0·03	} 0·44	trace
Na_2O	0·0141	1·59	0·41		0·93
Total	0·8979	100·00			100·00
Weight taken	0·8981				

The percentage composition of the silicate approaches very closely to the corresponding silicate in the Linn County meteorite as analysed by Rammelsberg.[1]

24. The undecomposed material being insoluble in water, the alkalies must be present as constituents of an insoluble compound, presumably felspar; the presence of the latter is further suggested by the fact that the dyad constituents are insufficient to form an aluminous pyroxene with the alumina and silica.

[1] Monatsb. Ak. Wiss. Berlin, 1870, p. 458.

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The CaO cannot be wholly present as a constituent of lime-felspar ($CaO \cdot Al_2O_3 \cdot 2SiO_2$); for in such case the oxygen of the Al_2O_3 must have been 3·57 instead of 2·27, without the alumina required for the soda-felspar being taken into account.

Hence it is reasonable to assume:—

1. That all the alumina is due to felspar (an admixture of albite and anorthite).

2. That all the alkali is due to felspar (albite).

3. That the excess of lime above that required to form felspar is a constituent of the remaining silicate (enstatite).

With these assumptions the following numbers may be obtained:—

The oxygen of $(Na,K)_2O$ being 0·44, that of the Al_2O_3 and SiO_2 forming albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) will be respectively 1·32 and 5·28. The total oxygen of the Al_2O_3 being 2·27, there is left 0·95 for the oxygen of the Al_2O_3 forming anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$); the oxygen of the corresponding CaO and SiO_2 will thus be respectively 0·32 and 1·28.

We therefore have the following distribution of the oxygen:—

		Total Oxygen.	Oxygen of— Enstatite.	Albite.	Anorthite.
SiO_2	...	30·10	23·54	5·28	1·28
FeO	...	2·26	2·26	—	—
MnO	...	0·09	0·09	—	—
MgO	...	8·68	8·68	—	—
CaO	...	1·19	0·87	—	0·32
Al_2O_3	...	2·27	—	1·32	0·95
K_2O / Na_2O	...	0·44	—	0·44	—

The total oxygen of the bases of the enstatite, namely 11·9, is slightly more than half that of the silica (23·54). On the other hand, the original constituents of the meteorite have been digested first with hydrochloric acid and then with sodic solution; the latter, while removing the free silica, would be expected to act to some extent on the silicates which resisted the acid, and to carry away the resultant silica, alumina and lime, leaving the corresponding oxides of iron and magnesia from the decomposed enstatite as part of the final residue.

25. The above distribution of oxygen corresponds to the following composition for the silicates themselves:—

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	Enstatite.	Felspar. Albite.	Felspar. Anorthite.	Total.
SiO_2 ...	44·44	9·97	2·42	56·83
FeO ...	10·19	—	—	10·19
MnO ...	0·39	—	—	0·39
MgO ..	21·81	—	—	21·81
CaO ...	3·04	—	1·13	4·17
Al_2O_3 ...	—	2·78	2·06	4·84
K_2O ...	—	0·18	—	0·18
Na_2O ...	—	1·59	—	1·59
		14·52	5·61	
	79·87	20·13		100·00

26. The composition of the above felspar is

		Percentages.	Calculated for Oligoclase (Ab_3An_1).
SiO_2	12·39	61·55	62·1
CaO	1·13	5·61	5·3
Al_2O_3	4·84	24·04	23·9
K_2O	0·18	0·90 } 8·8	8·7
Na_2O	1·59	7·90 }	
	20·13	100·00	100·0

27. The percentage composition of the above enstatite is

	Zomba Enstatite.	Lodran Enstatite.
SiO_2 ...	55·64	55·35
FeO ...	12·76	12·13
MnO ...	0·49	—
MgO ...	27·31	32·85
CaO ...	3·80	0·58
	—	Al_2O_3 0·60
	100·00	101·51

The numbers thus obtained for the Zomba enstatite are very similar to those obtained by Professor Tschermak for the Lodran enstatite: in the latter case the enstatite grains were so coarse that they could be picked out and a sufficient amount be separated for a special analysis.[1]

[1] Sitzungsb. Ak. Wien, 1870, Band 61, Abtheil. 2, p. 465.

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28. The mineral composition of the undecomposed material is

Enstatite	...	79·87	78·71
Oligoclase	...	20·13	19·84
Chromite	...	1·47	1·45
		101·47	100·00

Specific gravity of the Zomba enstatite.

29. Since the proportions by weight of the three constituents of the undecomposed material and the specific gravities of two of them (felspar and chromite) are known, it is now possible from the specific gravity of the mixture (§ 14) to calculate the specific gravity of the third constituent (enstatite). The specific gravity of oligoclase Ab_3An_1 is 2·66: that of chromite varies from 4·32 to 4·57 (Dana), the mean of which is 4·44: that of the mixture was found to be 3·171 (§ 14). The total volume of a mixture being the sum of the volumes of the constituents, it follows that, if x be the specific gravity of the enstatite,

$$\frac{78{\cdot}71}{x} + \frac{19{\cdot}84}{2{\cdot}66} + \frac{1{\cdot}45}{4{\cdot}44} = \frac{100}{3{\cdot}171}.$$

Whence x is 3·314.

The specific gravity of the Lodran enstatite was directly determined by Professor Tschermak to be 3·313.

Undecomposed material: Amount of action of hydrochloric acid and sodic solution.

30. The trace of undecomposed material, which, after treatment with hydrofluoric and sulphuric acids, weighed 0·0014 (§ 17), must before that treatment have weighed 0·0017 (§ 19); hence SiO_2 is 0·0746: and the total amount of undecomposed silicate is 0·0017+0·8807+0·0368 or 0·9187; for ignition does not appreciably alter the weight of the undecomposed material (§ 18). After deduction of SiO_2 0·0049 due to the sodic solution itself (§ 13), we have, for the SiO_2 due to the silicate, 0·0697.

For the hydrochloric acid extract:—

Fe_2O_3,Al_2O_3,SiO_2 0·0150 consisted of Fe_2O_3 0·0140 (corresponding to FeO 0·0127), Al_2O_3 0·0009, SiO_2 *nil*.

Deducting 0·0054 from $Mg_2P_2O_7$ 0·0649 as being really $Ca_2P_2O_7$ due to the action of the nitric acid on the porcelain (§ 20), we have $Mg_2P_2O_7$ 0·0595, corresponding to MgO 0·0215. Collecting the results:—

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	Acid Extract.	Sodic Extract.	Total Extract.
SiO_2	—	0·0697	0·0697
FeO	0·0127	—	0·0127
MnO	—	—	—
MgO	0·0215	—	0·0215
CaO	0·0076	0·0023	0·0099
Al_2O_3	0·0009	0·0062	0·0071
K_2O, Na_2O	undet.	undet.	undet.
		Total extract	0·1209
		Undecomposed residue	0·9187
		Weight found	1·0396
		Weight taken	1·0388

Hence it follows that when the undecomposed material is subjected to the action of hydrochloric acid and sodic solution in the same way and for the same length of time as in the analysis of the mixed powder itself, no less than 11·64 per cent. pass into the acid or sodic solution. As there is little alumina in the acid extract, either the felspar is only very slightly attacked by the acid, or the alumina is set free in such a form as to be only with difficulty soluble in the acid, though removable by the sodic solution[1]; more probably the greater part of the decomposition of the felspar is due to the sodic solution itself.

If we allow soda in sufficient proportion to form oligoclase with the alumina (§ 24) the percentage composition of the total extract is

SiO_2	56·44
FeO	10·29
MnO	—
MgO	17·41
CaO	8·02
Al_2O_3	5·75
K_2O, Na_2O	2·09
	100·00

The total extract has thus nearly the same composition as the original mixture (§ 23). The chief part of the solvent action on the enstatite is

[1] Jour. Chem. Soc. vol. 41, 1882, Transactions, p. 159.

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due to the acid; the silica set free by this action is removed by the sodic solution, which at the same time acts to some extent on the felspar, taking all the constituents into solution, and probably to some extent on the enstatite, removing the silica and lime but leaving its oxide of iron and magnesia in the final residue. The corresponding oxide of iron and magnesia left in the undecomposed residue by the action of the previous sodic solution will have passed into the acid extract.

Unattracted material: Treatment with mercuric solution.

31. Fe_2O_3 0·0021 (§ 9) corresponds to Fe 0·0015. Hence the total amount of alloy extracted by the mercuric solution from 4·9856 grams of the unattracted material was at most 0·0022, containing 31·82 per cent. of nickel; as already stated, the high percentage of the nickel was already manifested by the colour of the extract. This again points to the easy oxidation of the iron of the finer particles of nickel-iron during the exposure to the air in the course of the magnetic separation and afterwards; the nickel being less easily oxidised and less readily attracted by the magnet, the percentage of the nickel in the metallic portion still left with the unattracted material will be higher than in the original nickel-iron.

Unattracted material: Alkalies.

32. K_2PtCl_6 0·0040 (§ 8) corresponds to KCl 0·0012; 0·0036, adherent to the filter and ignited, if taken as Pt·2KCl, corresponds to KCl 0·0016; making altogether KCl 0·0028.

From the blank experiment (§ 22) the KCl due to the reagents is 0·0021; hence only KCl 0·0007 can be assigned to the silicate.

The mixed chlorides due to the silicate weigh 0·0135 (§ 8) − 0·0021 (§ 22), or 0·0114; the NaCl is thus 0·0107.

These amounts of NaCl and KCl correspond respectively to Na_2O 0·0057 and K_2O 0·0004 for 0·4815 of material, and to Na_2O 1·18 and K_2O 0·08 per cent.

As the total amount of matter extracted from the unattracted material by boiling water amounted to only 0·26 per cent. and part of it consisted of calcium and magnesium, it is inferred that the alkalies were present in the unattracted material as constituents of an insoluble compound, presumably felspar.

Unattracted material: First Portion.

33. The trace of undecomposed material which, after treatment with hydrofluoric and sulphuric acids weighed 0·0039 (§ 10), must before that treatment have weighed 0·0047 (§ 19); and the total amount of undecom-

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posed material is 0·0047+0·9186+0·1328 or 1·0561, for ignition does not appreciably alter the weight of the undecomposed material (§ 18).

The true SiO_2 is 0·4909−0·0047 or 0·4862: but of this 0·0049 are due to the sodic solution itself (§ 13): the SiO_2 really due to the silicate is thus 0·4813. Of the Fe_2O_3,Al_2O_3,SiO_2 0·0048, the Fe_2O_3 was small and probably only that from the sodic solution itself 0·0009 (§ 13), the SiO_2 was 0·0031 (making the total SiO_2 0·4844) and (by deficit) Al_2O_3 is 0·0008.

The Fe_2O_3,Al_2O_3,SiO_2 0·4639 from the acid extract consists of Fe_2O_3 0·4578 (corresponding to FeO 0·4120), Al_2O_3 0·0040 (and SiO_2 0·0021 due to action on the vessels).

Further 2·5065 of unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1412, which is itself equivalent to FeO 0·1155; as this iron is in the acid extract, only FeO 0·2965 (*i.e.* 0·4120−0·1155) is due to the silicate.

MnS 0·0068 corresponds to MnO 0·0055.

[NiO 0·0001 may be neglected in the calculations.]

Hence we have:—

		Percentages.
Undecomposed material ...	1·0561	42·13
Troilite	0·1412	5·63
SiO_2	0·4844	19·33
FeO	0·2965	11·83
MnO	0·0055	0·22
MgO	undet.	undet.
CaO	undet.	undet.
Acid extract 0·0040 / Sodic extract 0·0008 Al_2O_3 ...	0·0048	0·19
K_2O	undet.	undet.
Na_2O	undet.	undet.
Total	1·9885	79·33
Weight taken	2·5065	100·00

Unattracted Material: Second Portion.

34. The amount of volatile material corresponding to 2·7333 of the material taken for analysis would be 0·0680 (§ 11), and the weight of the pure material was thus 2·6653.

The trace of undecomposed material which after treatment with hydrofluoric and sulphuric acids weighed 0·0017 (§ 11) must before that treatment have weighed 0·0021 (§ 19): and the total amount of undecomposed material is 0·0021+1·0981+0·0516, or 1·1518, for the weight of the undecomposed material is not appreciably altered by the ignition (§ 18).

The true SiO_2 is thus 0·5296−0·0021 or 0·5275; but of this 0·0049 is due to the sodic solution itself (§ 13); the SiO_2 really due to the silicate being therefore 0·5226.

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The Fe_2O_3,Al_2O_3,SiO_2 0·0065 consists of Fe_2O_3 0·0020, Al_2O_3 0·0035 and SiO_2 0·0010 (making the total SiO_2 0·5236): deducting Fe_2O_3 0·0009 as due to the sodic solution itself, Fe_2O_3 0·0011 has passed into the sodic solution from the silicate (possibly through finely divided silicate passing through the pores of the filter).

The Fe_2O_3,Al_2O_3,SiO_2 0·5013 of the acid extract consists of Fe_2O_3 0·4960, Al_2O_3 0·0019 and SiO_2 0·0034 (due to action on the vessels).

(NiS ignited 0·0012 may be omitted in the calculations.)

MnS 0·0074 corresponds to MnO 0·0060.

The $Mg_2P_2O_7$ (pure) is 1·3884 (§ 11) − 0·0054 (§ 20) or 1·3780, corresponding to MgO 0·4989.

The total Fe_2O_3 is 0·4960 + 0·0011 or 0·4971, corresponding to FeO 0·4474: further, 2·6653 of the unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1502, which itself is equivalent to FeO 0·1259: as this iron is in the acid extract, only 0·3215 (*i.e.* 0·4474 − 0·1259) of FeO is due to the silicate.

The total CaO obtained is 0·0018 + 0·0105 or 0·0118; from this must be deducted 0·0005 as due to the sodic solution (§ 13).

Also 2·6653 of the unattracted material contain (§ 22) K_2O 0·0022, Na_2O 0·0315; and the 1·1518 of undecomposed material contain (§ 22) K_2O 0·0021, Na_2O 0·0182: hence there must have passed into the acid and alkaline solutions K_2O 0·0001 (or *nil*) and Na_2O 0·0133.

Collecting the results we have:—

			Percentages.
Undecomposed material ...	...	1·1518	43·21
Troilite	...	0·1502	5·64
SiO_2	...	0·5236	19·65
FeO	...	0·3215	12·06
MnO	...	0·0060	0·23
MgO	...	0·4989	18·72
CaO	...	0·0113	0·42
Acid extract 0·0019 / Sodic extract 0·0035	Al_2O_3 ...	0·0054	0·20
K_2O	...	*nil*	*nil*
Na_2O	...	0·0133	0·50
	Total	2·6820	100·63
	Weight taken	2·6653	100·00

Unattracted Material: Third Portion.

35. The trace of undecomposed material which, after treatment with hydrofluoric and sulphuric acids weighed 0·0026 (§ 12), must before that treatment have weighed 0·0032 (§ 19); and the total amount of undecomposed material is 0·0032 + 0·8107 + 0·0241, or 0·8380, for the undecomposed material is not appreciably altered in weight by ignition (§ 18)

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The true SiO_2 is thus 0·4208 − 0·0032 or 0·4176, but of this 0·0049 is due to the sodic solution itself (§ 13); hence the SiO_2 really due to the silicate is 0·4127.

The Fe_2O_3,Al_2O_3,SiO_2 0·0069 consists of Fe_2O_3 0·0037, Al_2O_3 0·0031 (SiO_2 0·0001, making the total SiO_2 0·4128).

Deducting Fe_2O_3 0·0009 as due to the sodic solution itself, Fe_2O_3 0·0028 has passed into the sodic solution from the silicate (possibly through finely divided silicate passing through the pores of the filter).

The Fe_2O_3,Al_2O_3,SiO_2 0·8775 consists of Fe_2O_3 0·8755, Al_2O_3 0·0002 (SiO_2 0·0018, due to the action on the vessels).

CuS (ignited) 0·0008 and Ni(Co) 0·0010 may be neglected during the calculation.

MnS 0·0056 corresponds to MnO 0·0046.

The $Mg_2P_2O_7$ (pure) is 1·0958 (§ 12) − 0·0054 (§ 20) or 1·0904, corresponding to MgO 0·3948.

The total Fe_2O_3 is 0·8755 + 0·0028 or 0·8783, corresponding to FeO 0·8405; further, 2·0817 of the unattracted material contain an amount of sulphur (§ 7) corresponding to FeS (troilite) 0·1145 which itself corresponds to FeO 0·0986; as this iron is in the acid solution, only 0·8405 − 0·0986, or 0·2469, of FeO is due to the silicate.

The total CaO obtained is 0·0028 + 0·0107 or 0·0130; from this must be deducted 0·0005 as due to the sodic solution (§ 13).

Also 2·0817 of the unattracted material contain (§ 32) K_2O 0·0017, Na_2O 0·0241; and the 0·8380 of undecomposed material contains (§ 22) K_2O 0·0015, Na_2O 0·0133: hence K_2O 0·0002 (or *nil*) and Na_2O 0·0108 must have passed into the acid and sodic extracts.

Collecting these results we have:—

			Percentages.
Undecomposed material ...	...	0·8380	41·25
Troilite	...	0·1145	5·64
SiO_2	...	0·4128	20·32
FeO	...	0·2469	12·15
MnO	...	0·0046	0·23
MgO	...	0·3948	19·43
Acid extract 0·0107 / Sodic extract 0·0018	CaO ...	0·0125	0·61
Acid extract 0·0002 / Sodic extract 0·0031	Al_2O_3 ...	0·0033	0·16
K_2O	...	*nil*	*nil*
Na_2O	...	0·0108	0·53
	Total	2·0882	100·32
	Weight taken	2·0817	100·00

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86. Bringing the results together for convenience of comparison, we have:—

	I.	II.	III.	Mean.	Oxygen.	
Undecomposed material	42·18	48·21	41·25	42·20	—	
[Troilite ...	5·63	5·64	5·64	5·64]	—	
SiO_2	19·38	19·65	20·32	19·77	10·47	
FeO	11·88	12·06	12·15	12·01	2·67	10·46
MnO... ...	0·22	0·28	0·28	0·28	0·05	
MgO... ...	undet.	18·72	19·48	19·07	7·59	
CaO	undet.	0·42	0·61	0·51	0·15	
Al_2O_3 ...	0·19	0·20	0·16	0·18	0·08	
[Na_2O... ...	undet.	0·50	0·58	0·51]	0·18	
Total	79·38	100·68	100·32	100·12		
Weight taken	100·00	100·00	100·00	100·00		

In the analysis of the first portion, the three successive extractions with acid were allowed to proceed for 1½ hours, 2 hours and 2 hours, respectively; in the case of the second portion the times were 2 hours, 1¾ hours, and 2 hours, respectively; in that of the third portion, each extraction lasted two hours. As it has been shown (§ 80) that no less than 11·64 per cent. of the undecomposed material are decomposed during such extractions, it follows that the variation from 41·25 per cent. to 48·21 per cent. in the amount of residue in the three analyses is sufficiently accounted for by variations of circumstances during the extractions; for instance, of the times for which each extraction is allowed to proceed, the temperature of the extracting acid, the frequency of renewal of the evaporated water, and so on. The actual extract corresponds very closely to olivine, and neglecting the soda and alumina has the following composition:—

		Per cent.	Oxygen.		Muddoor.	Linn County.
SiO_2	19·77	38·25	20·26		38·32	38·80
FeO	12·01	23·23	5·16		23·29	21·31
MnO	0·23	0·45	0·10	20·28	—	—
MgO	19·07	36·89	14·68		36·90	39·89
CaO	0·51	1·18	0·34		1·07	—
				Al_2O_3	0·42	—
	51·59	100·00			100·00	100·00

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This composition is virtually identical with that calculated by Crook[1] for the olivine of the Muddoor meteorite and also is very nearly that of the "decomposed portion" of the Linn County stone as analysed by Rammelsberg[2].

Some of the silica, however, must have been originally in combination with the soda and alumina which have been neglected, and further a small quantity of the remaining constituents is due to the action of the hydrochloric acid and sodic solution on the enstatitic silicate.

37. An estimate of the quantities due to the action on the refractory silicates can be obtained by assuming that they are in the same proportion to the undecomposed residue as in the analysis mentioned in § 30. But the estimate will be only approximate, for in the analysis of the mixture the strength of the acid and its decomposing effect are diminished owing to the action of the olivine: further the gelatinous silica from the olivine will partially protect the other silicates from the acid; and the presence of the compounds due to the decomposition of the olivine may have a disturbing effect on the action of the acid.

These considerations being disregarded, it follows from § 30 that when the residue weighs 88·36 the following amounts due to the refractory silicates have passed into solution:—SiO_2 6·57, FeO 1·20, MgO 2·03, CaO 0·93, Al_2O_3 0·67, R_2O 0·24; hence for the residue 42·20 the corresponding amounts are SiO_2 3·14, FeO 0·57, MgO 0·97, CaO 0·44, Al_2O_3 0·32, R_2O 0·11, making in all 5·55. Deducting these amounts from the quantities found in the solution (§ 36), we have for the less refractory silicate itself:—

SiO_2 16·63, FeO 11·44, MnO 0·23, MgO 18·10, CaO 0·07, Al_2O_3 −0·14, Na_2O 0·40.

Omitting the CaO, Na_2O, Al_2O_3 as being possibly extraneous, we have the following composition:—

		Per cent.	Oxygen.		Muddoor (observed).	
SiO_2	16·63	35·84	18·98		SiO_2	35·46
FeO	11·44	24·65	5·48	21·11	FeO	24·36
MnO	0·23	0·50	0·11			
MgO	18·10	39·01	15·52		MgO	38·61
					CaO	1·13
					Al_2O_3	0·44
	46·40	100·00				100·00

[1] Die Chemische Natur der Meteoriten, von C. Rammelsberg, 1879, p. 54.

[2] Monatsb. Ak. Wiss. Berlin, 1870, p. 459.

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The nearness of the oxygen-ratio to that of olivine is thus lessened by the deduction of the quantities resulting from the action on the refractory silicates; but the composition is almost identical with that observed by Crook for the decomposable silicate of the Muddoor meteorite.

According to this interpretation, the total amount of enstatite, felspar and chromite in the unattracted material would be 47·75 per cent., 42·20 per cent. remaining undecomposed and 5·55 per cent. passing into the acid and sodic solution.

Unattracted Material: Chromite.

38. Since the unattracted material yields 42·20 per cent. of undecomposed residue (§ 36) and the latter itself contains (§ 28) 1·45 per cent. of chromite, the unattracted material must contain 0·61 per cent. of chromite. By direct extraction with hydrofluoric and sulphuric acids only 0·35 per cent. was isolated, but probably some is decomposed and passes into solution (§ 6). Similarly, the chromium obtained during the determination of the alkalies corresponds to only a small fraction of the total chromite.[1]

39. The enstatite and oligoclase of the unattracted material will thus (§§ 37, 38) amount to (47·75 − 0·61 or) 47·14 per cent., and this will consist (§ 28) of 37·65 of enstatite and 9·49 of oligoclase; the troilite is 5·64 per cent. (§ 36): hence the olivine amounts to 46·61 per cent. The mineral composition of the unattracted material (neglecting minute quantities of nickel-iron and schreibersite) will therefore be

			Total weight.
Olivine	...	46·61	5·7894
Enstatite	...	37·65	4·6764
Oligoclase	...	9·49	1·1787
Troilite	...	5·64	0·7005
Chromite	...	0·61	0·0758
		100·00	12·4208 grams.

Attracted Material: First Set of Extracts.

40. The Fe_2O_3,P_2O_5,SiO_2 0·4933 (§ 2) consists of Fe_2O_3 0·4895 (corresponding to Fe 0·3427), P_2O_5 0·0003 (corresponding to P 0·0001), (SiO_2 0·0028 due to the action on the vessels).

The phosphorus being present as Fe_2NiP (schreibersite) requires Fe 0·0004, Ni 0·0002.

The Ni(Co) due to nickel-iron (§ 2) is thus 0·0487 − 0·0002 or 0·0485.

[1] Mineralogical Magazine, 1894, vol. 10, p. 307.

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Hence we have :—

Extracted :—Nickel-iron	Fe	0·0842	0·3908
	Ni(Co)	0·0485	
Schreibersite	...	...	0·0007
Residue (§ 3)	...	...	0·3385
		Total	0·7300
		Weight taken	0·7421

No great stress can be laid on the loss of weight (0·0121), owing to the character of the necessary operations.

The percentage composition of the nickel-iron (0·3908) which has passed into solution is Fe 87·59, Ni(Co) 12·41.

Further, $3K_2SO_4.2CoSO_4$ 0·0166 corresponds to Co 0·0024 : hence the percentage composition of the Ni(Co) is Ni 95·07, Co 4·93, and that of the nickel-iron is Fe 87·59, Ni 11·80, Co 0·61, Cu *trace*.

Attracted Material : Second Set of Extracts.

41. Fe_2O_3 0·0439 (§ 3) corresponds to Fe 0·0307 ; and the Ni(Co) is 0·0135.

Hence we have :—

Extracted :—Nickel-iron	Fe	0·0307	0·0442
	Ni(Co)	0·0135	
Residue (§ 4)	...	...	0·2850
		Total	0·3292
		Weight taken	0·3366

As before, no stress can be laid on the loss of weight (0·0074) ; the percentage composition of the nickel-iron (0·0442) extracted in the second series of operations is Fe 69·46, Ni(Co) 30·54.

Attracted Material : Residue.

42. The Fe_2O_3,SiO_2 0·0450 (§ 4) consists of Fe_2O_3 0·0447 (corresponding to Fe 0·0306) and SiO_2 0·0013 (due to the action on the vessels).

$Mg_2P_2O_7$ 0·1137 corresponds to MgO 0·0412 (having regard to the smallness of this amount, the action of the nitric acid on the vessels must likewise have been small, and no deduction is made) ; the MgO being due to the silicates, other constituents in corresponding proportion must likewise be due thereto ; hence the quantities will be (§ 35) :—

SiO_2 0·0420, MgO 0·0412, FeO 0·0245, MnO 0·0005, CaO 0·0011, making altogether 0·1093 of silicate decomposed by the hydrochloric acid ; this leaves SiO_2 0·0027 (namely 0·0447 − 0·0420) unallotted ; the above quantities are only approximate, for the enstatitic and felspathic

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silicates are acted on by the acid and sodic solutions, and their proportions to the olivine are probably different from those which obtain in the unattracted material. Further, FeO 0·0245 of the silicate corresponds to Fe 0·0191 which is included in the above total Fe 0·0306; the Fe due to the alloy itself is thus 0·0115.

Hence we have:—

Final residue (enstatite, &c.) ...	0·1409 (§ 4)
Silicate decomposed (olivine, &c.) ...	0·1093
Fe	0·0115
Ni(Co)	0·0072
Unallotted SiO_2	0·0027
Total	0·2716
Weight taken	0·2757

The loss in this case (0·0041) is, partly at least, oxygen: the amount of oxygen necessary to convert the whole of the iron into Fe_3O_4 would be 0·0044. That there is a certain amount of unoxidised metal present is shown by the effervescence of the material with the acid (§ 4): that there is oxide present is indicated by the extreme slowness of action of the mercuric solution on the material (§ 3). As there is only a small proportion of black opaque matter visible in the thin sections when examined with the microscope, and this is probably chromite, the oxidation had probably taken place during the analysis itself, as already suggested (§ 2). The iron and nickel in this residue corresponding to original metal will thus be Fe 0·0115, Ni(Co) 0·0072, corresponding to 0·0187 of alloy having the percentage composition Fe 61·50, Ni(Co) 38·50.

48. Hence we have the following results:—

	Nickel-iron.	Fe.	Ni(Co).	Percentage of Ni(Co).
First Extracts ...	0·3908	0·3423	0·0485	12·41
Second Extracts ...	0·0442	0·0307	0·0135	30·54
Residue	0·0187	0·0115	0·0072	38·50

Hence, of the total nickel-iron contained in the attracted material, 86·13 per cent. are removed in the first set of extractions, 9·75 in the second, and the remaining 4·12 is left partly as oxide and partly as metal, the latter protected from the mercuric solution by enclosing oxide or silicate. The variation of the percentage of nickel (cobalt) from 12·41 to 38·50, as the extraction proceeds, does not necessarily imply the existence of different alloys of nickel-iron in the material; it is probably a

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mere result of the easier oxidation of the iron than the nickel during exposure of the alloy to the atmosphere in the course of the operations.

Attracted Material: Mineral Composition.

44. Calculation, from these numbers, of the composition of the various residues leads to the following composition for the attracted material:—

			Grams.
Nickel-iron	...	...	1·2422
Olivine	...	...	0·3373
Enstatite	...	...	0·3474
Oligoclase	...	...	0·0875
			2·0144;

for the proportion of the decomposed to the undecomposed silicate is known from § 42, and the proportion of the enstatite to the oligoclase may be taken to be the same as for the previous similar material (§ 28).

Mineral Composition of the Fragment.

45. From §§ 39, 44, the mineral composition of the complete fragment was:—

		Grams.	Zomba. Percentages.	Linn County.[1] Percentages.
Nickel-iron	...	1·2422	8·61	10·54
Olivine	...	6·1267	42·44	41·85
Enstatite	...	5·0288	34·80	41·24
Oligoclase	...	1·2662	8·77	
Troilite	...	0·7005	4·85	6·37
Chromite	...	0·0758	0·53	—
		14·4352	100·00	100·00

Mineralogical Relationship to other Meteoric Stones.

The Zomba meteorite thus consists of a stony material composed of olivine and enstatite in nearly equal quantity admixed with a certain amount of oligoclase; embedded in this stony material are nickel-iron and troilite in considerable quantity and small amounts of chromite and schreibersite. In the aspect of the thin sections as seen under the microscope, in the proportions of the mineral constituents (§ 45), in the percentage chemical composition of the silicate decomposed by hydrochloric acid (§ 36) and in that of the silicate obtained as a residue after the action of the acid and the sodic solution (§ 28), the Zomba meteorite

[1] Monatsb. Ak. Wiss. Berlin, 1870, p. 458.

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closely resembles the stone which fell in Linn County, Iowa, U.S.A., on 25th February, 1847; different parts of one meteoric stone would generally show greater differences. The composition here assigned to the Zomba enstatite, after analysis of what is interpreted to be a mixture of enstatite and oligoclase, is very near to that found by Professor Tschermak for the coarse grains of enstatite which he was able to isolate from the Lodran stone for chemical determination (§ 27), and the specific gravity as calculated for the Zomba enstatite from the specific gravity of the mixture is virtually identical with the specific gravity directly determined by Professor Tschermak for the isolated Lodran mineral (§ 29). Further, it is found that the "undecomposed residue," when itself subjected to the treatment used in the analysis of the unattracted material, loses nearly 12 per cent. of its weight; the enstatite is chiefly acted upon by the acid, the oligoclase by the sodic solution (§ 30).

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Marshite, Miersite and Iodyrite from Broken Hill, New South Wales.

By L. J. Spencer, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read April 5th, 1898.]

MINERALS containing iodine as an essential constituent are of rare occurrence in nature. The most common, and that first described, is silver iodide, which was analysed by Vauquelin in 1825; hexagonal crystals of iodyrite were described by Des Cloizeaux in 1854. Other iodides are marshite and the new mineral miersite; iodobromite and schwartzembergite also contain considerable amounts of iodine. The existence of mercury iodide seems to be doubtful; the supposed mercury iodide from Broken Hill consists of an intimate mixture of cinnabar and iodyrite.[1] Two iodates are also known, namely lautarite and dietzeite.

I. Marshite.

Crystals of "native copper iodide" were discovered at Broken Hill, New South Wales, by C. W. Marsh,[2] in 1892. The results of his qualitative analysis showed the presence of copper and iodine, and the crystallographic form was stated to be "tetragonal-hemihedral." In an abstract of this paper Prof. Miers[3] pointed out with reference to the statement of the crystalline form: "hier ist wohl ein Fehler, denn Krystalle von derselben Substanz, die im britischen Museum sich befinden, sind tetraëdrisch und gehören dem regulären Systeme an."

It is possible that Marsh made his crystallographic observations on either wulfenite or stolzite, both of which minerals have several times

[1] Silver iodide is extracted when the substance is digested with a solution of potassium iodide. See also J. B. Jaquet, "Geology of the Broken Hill Lode and Barrier Ranges Mineral Field, New South Wales," Memoirs Geol. Survey, N.S.W., 1894, Geol. Ser. No. 5, p. 90.

[2] Journal and Proc. Roy. Soc. New South Wales, for 1892 [1893], XXVI. 326 (Abstract Min. Mag. XI. 236). The principal characters of the mineral were verified by Prof. A. Liversidge, who in an accompanying note (p. 328) proposed the name marshite. A later brief description of the mineral is given by G. W. Card, Records Geol. Survey, N.S.W. 1895, IV, 131.

[3] Zeits. Kryst. Min. 1894, XXIV. 207.

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been sent to the British Museum labelled as marshite. The crystal of marshite measured by Prof. Miers was isotropic; it was bounded by faces of the cube and of two tetrahedra, and was twinned on a tetrahedron face.

Tetrahedral crystals of cuprous iodide have been prepared by E. Meusel[1] by the action of hydriodic acid on metallic copper or on copper-glance. Although a quantitative analysis has not been made of marshite, it is without doubt identical with this artificial cuprous iodide.

Occurrence: *Physical Characters.*—The description of the mineral to be now given is based on an examination of seven specimens in the British Museum collection, all of which are from Broken Hill. Labels with three of the specimens give the exact locality as the Broken Hill Proprietary Consols Mine.

The crystals of marshite are usually scattered over the surface of platy or cellular psilomelane, which in turn encrusts an incoherent mixture of limonite and cerussite[2] with grains of quartz and grains and dodecahedra of brown garnet. Sometimes copper-glance or cuprite is also present, the latter in good crystals altered on the surface to malachite. On one specimen the psilomelane forms a thin coating on blue opalescent quartz. The matrix of another specimen consists of massive and crystallised cuprite, with some native copper, quartz and brown garnet.

The faces of the crystals are bright and have a resinous to adamantine lustre. The colour varies from very faint yellow to dark brick-red, but the streak is always bright lemon-yellow. For an almost colourless crystal to give a bright yellow streak is very striking. Exposure to bright sunlight for several days does not affect the colour. Only the very pale coloured crystals are transparent, the others varying from translucent to almost opaque according to the depth of colour.

An important character not before noticed is the perfect dodecahedral cleavage, $d\{110\}$. The fracture is conchoidal, and the mineral is rather brittle; hardness $2\frac{1}{2}$ on Mohs' scale.

The crystals and cleavage flakes are as a rule optically isotropic, but sometimes a broken crystal shows uneven extinction, as if strained. The refractive index was approximately[3] determined for light of different colours with a colourless transparent prism of which the refracting

---

[1] Ber. deutsch. chem. Ges. 1870, III. 123.

[2] The cerussite shows stellated groups with twin-plane $m(110)$. A measured crystal was twinned on $r(130)$, and agreed closely with Mügge's description of cerussite from Broken Hill (Neues Jahrb. Min. 1897, II, 78).

[3] The images were somewhat scattered.

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angle of 35° 13½′ (calculated 35° 16′) was formed by a tetrahedron face and a dodecahedral cleavage.

$$n_{(Li)} = 2{\cdot}313,\ n_{(Na)} = 2{\cdot}346,\ n(Tl) = 2{\cdot}385.$$

For the extreme visible ends of the spectrum of white light the refractive indices are approximately 2·25 and 2·7. The dispersion is thus considerably higher than in diamond.

Crystallographic Characters.—Two types of the marshite crystals are to be distinguished; they may occur separately or together on the same specimen. On one specimen the crystals of type *A* pass into a continuous crust of ash-grey marshite, on which the larger and darker coloured crystals of type *B* are deposited. The crystals of the two types therefore appear to belong to two different periods of growth.

Type A.—Bright crystals usually scattered singly over the matrix; they are of minute size, but on one specimen measure 1·5 mm. across. The colour is usually pale wine-yellow, but varies from almost colourless to brighter yellow. Faces of the cube and of both tetrahedra are prominently developed (compare Fig. 1, p. 46), and some of the crystals are cubo-octahedral in habit.

Type B.—Crystals of this type are larger and average 1—1·5 mm. across. They vary in colour from orange-red to brick-red. The habit is distinctly tetrahedral, owing to the small development or absence of one tetrahedron, and of the cube. The crystals are often grouped together in parallel position.

Although a dozen crystals (of both types) were measured on the goniometer, the only forms noticed were the cube $a\{100\}$ and the two tetrahedra $+o\{111\}$ and $-o\{1\bar{1}1\}$. The measurements were usually good, and agreed closely with the calculated angles of cubic crystals.

The faces of both tetrahedra are bright and smooth; they show no difference in character, and on some crystals of type *A* they are of equal size. The cube faces are slightly striated parallel to their intersection with either the larger or the smaller tetrahedron faces. On crystals of type *B* the faces of the large tetrahedron are often striated and stepped parallel to their intersections with the cube faces, the edges of the steps being usually bounded by narrow planes in twin position relative to the main crystal. Juxtaposed twins with a tetrahedron face as twin-plane are frequent, and angles of 15°48′ ($=oa$) were often measured. Some crystals are twinned on more than one tetrahedron face.

The characters described above are remarkably like those of zinc-blende, and the refractive index is also nearly the same; the crystallographic

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characters—habit, twinning and cleavage—are identical, and in fact some of the crystals, especially those of type *A*, are very similar in appearance to the crystals of yellow zinc-blende from the white dolomite of the Binnenthal in Switzerland, the figures of which given by Sadebeck and vom Rath may very well be taken to represent marshite.

Chemical Characters: Behaviour when heated.—Qualitative chemical tests made on crystals from two specimens showed the presence of only copper and iodine. These crystals, and also those from other specimens with one exception, when placed in a drop of cold dilute nitric acid, are quickly blackened on the surface owing to the liberation of iodine, and they are not reduced by zinc and sulphuric acid. Crystals from one specimen (of which the matrix is blue opalescent quartz) were found to contain a small amount of silver; these crystals are not blackened in cold dilute nitric acid, and they are reduced by zinc and sulphuric acid; they thus behave with these reagents like miersite (p. 42) and not like pure marshite (CuI.)

When heated on a microscope slide, the crystals become dark red and decrepitate; on cooling they regain their original colour. At a higher temperature the pure crystals blacken and decompose without fusing; but those which contain silver sometimes fuse to a reddish liquid, which on cooling solidifies to an aggregate of isotropic grains.

II. Miersite.

A preliminary account of miersite, named in honour of Dr. Henry A. Miers, F.R.S., Professor of Mineralogy in the University of Oxford, was given in *Nature*[1] for April 14th, 1898. A more detailed account has been deferred in the hope that sufficient material would be available for a quantitative chemical analysis. Six specimens of the mineral have now been found for the British Museum collection, but it would not be advisable to collect material for analysis from more than one, since the amount of copper varies in the different specimens.

Occurrence: Physical Characters.—All the specimens are from Broken Hill, New South Wales. The associated minerals are cerussite, limonite, malachite, brown garnet, and quartz, with sometimes copper-glance and cuprite which have escaped alteration. The miersite occurs on the free surface of the specimens, usually as crystalline crusts or as aggregates of rather indistinct crystals. Distinctly developed crystals are less frequent

[1] "Miersite, a cubic modification of native silver iodide." By L. J. Spencer. Nature, 1898, LVII, 574. The minute crystals on one of the specimens there mentioned have since been shown to belong to type *b* of iodyrite (see p. 46 below).

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than in marshite. The crystals are sometimes about 2 mm. across, but usually they are much smaller.

The colour of the crystals and of the streak is canary-yellow, and it is not affected by exposure for several days to bright sunlight. The crystals are translucent, and have a resinous to adamantine lustre. The mineral is somewhat brittle, and has a hardness of $2\frac{1}{2}$: a crystal when crushed breaks into angular fragments without any distortion of the faces, and by this miersite is at once distinguished from iodyrite. The fracture is conchoidal, and there are, as in marshite, perfect cleavages parallel to the faces of the rhombic-dodecahedron, $d\{110\}$. Small fragments and cleavage flakes are transparent and, as a rule, perfectly isotropic.

Crystallographic Characters.—The crystallographic characters of miersite are exactly similar to those of marshite and zinc-blende. The habit varies from tetrahedral with narrow cube planes (compare Fig. 1, p. 46) to cubo-octahedral. Usually both tetrahedra are present and of different sizes, but they show no difference in surface characters. The crystals are frequently twinned, and this twinning may be more than once repeated, and on more than one tetrahedron face: as a result of this the angle $oa = 15°48'$ is of frequent occurrence. The faces are bright and smooth; those of the cube are sometimes striated parallel to the intersection with either the larger or the smaller tetrahedral faces. Tetrahedral faces show triangular striations and elevations, the edges of which are usually bounded by narrow planes in twin position relative to the main crystal. Although detailed measurements were made of more than a dozen crystals, these were the only forms noted. As a rule the measured angles only differed by a few minutes from the calculated cubic angles.

The habit of one of the measured crystals is that of a hemimorphic rhombohedral crystal of iodyrite with the forms $g\{55\bar{4}\}$ and $c\{111\}$. The planes prominently developed are three cube faces ($\bar{1}00$, $0\bar{1}0$, $00\bar{1}$), and one tetrahedron face (111), which is also the plane of twinning. On this crystal the perfect dodecahedral cleavage was purposely developed in five directions, and the cleavage flakes detached were perfectly isotropic. No pyroelectricity was detected on this, or any other crystal, by dusting a cooling crystal with red-lead and sulphur.

Chemical Characters: Behaviour when heated.—Qualitative chemical tests showed the presence of much silver and iodine, with varying amounts of copper. A very little chlorine may also be possibly present in some crystals. The mineral is not affected by dilute nitric acid, but is readily reduced by zinc and sulphuric acid. It is still hoped that sufficient material may be collected for a quantitative analysis.

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The optical behaviour of the material after fusion, as described below, gives an approximate idea of the relative proportions of silver iodide and copper iodide. In these experiments only small amounts of material need be used, and comparative experiments can be made on mixtures of artificially prepared silver iodide and copper iodide in known proportions.

Fragments when heated on a microscope slide exhibit a more or less gradual change in colour, passing through bright orange-yellow to brick-red. There is no change in the transparency and isotropic character of the crystals either when hot or when cold. When heated to a higher temperature the crystals fuse to a deep-red liquid which spreads out as a film under the cover-glass. On solidification the substance is reddish-yellow and optically isotropic, and appears to be perfectly homogeneous. As further cooling takes place the colour gradually changes to bright-yellow, when all at once isotropic pale yellow needles commence to grow and branch out at numerous isolated points all over the field of view. These grow rapidly at the expense of the bright yellow substance, until the whole field is occupied by an intergrowth of two isotropic substances with sharp lines of demarcation between them. A little later the remaining bright yellow substance suddenly changes to very pale yellow birefringent iodyrite. This second change in state is the same as that which takes place with pure silver iodide (p. 49), and the sharp line separating the two modifications may be seen to sweep across the field of view from one side to the other; it does not, as in the first change of state, start independently from numerous isolated points.

The slide now, and when cooled to the ordinary temperature, shows an intergrowth of two substances: one isotropic and pale yellow, the other birefringent and paler in colour. The first usually forms a network of rods at angles of $70° - 75°$ or sometimes of nearly $90°$, the interspaces of which are occupied by strips of the birefringent material; the latter extinguish parallel to their length and are opposed to quartz in the same direction. The relative amounts of these two substances varies considerably for different crystals; usually there is little or none of the birefringent iodyrite, while for crystals to be described later (p. 44) the isotropic substance is subordinate.

When weighed amounts of precipitated silver iodide and copper iodide in various molecular proportions[1] from AgI + CuI to 8AgI + CuI were

[1] G. F. Rodwell has determined the sp. gr., melting points and coefficients of expansion and contraction of such mixtures, Proc. Roy. Soc. 1881, XXXIII, 143; Phil. Trans. 1883 (1882), CLXXIII, 1154, Plate 96; and M. Bellati and R. Romanese, from their determinations of specific heat and heat of transformation, conclude that molecular compounds are formed by silver iodide and copper iodide. Proc. Roy. Soc. 1882, XXXIV, 104; Phil. Trans. 1883 (1882), CLXXIII, 1169.

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intimately mixed and fused on a microscope slide, the same phenomena were observed as with the natural crystals. The mixture 4AgI + CuI gave a slide showing the isotropic network with only a speck here and there of birefringent iodyrite. When more copper iodide was present the whole slide remained isotropic, while with more silver iodide more of the birefringent substance was formed.

The growth of the pale yellow isotropic crystals in the bright yellow isotropic substance is perhaps scarcely a simple change in state from an amorphous (or possibly cubic) modification to a cubic modification, since the crystals appear to have a definite composition (probably 4AgI.CuI), and the residue left after their growth consists of pure silver iodide. If this be the case, then during crystallisation there must be a migration of silver iodide through the solid material. It is, however, of course possible, that on the solidification of the material, two cubic substances, 4AgI.CuI and AgI, are formed, and that each of these undergoes independently a change in state as the temperature falls first to one and then to another definite point.

Intergrowth with Iodyrite.—Crystals from two of the specimens differ considerably from those described above. They have the hardness and cleavage of miersite, but are paler in colour, and are doubly refracting. As a rule they are repeatedly twinned on two faces of the tetrahedron, and the prominent zone containing these two bright tetrahedral faces is deeply furrowed and striated. When viewed in polarised light across this striated zone, the crystals extinguish parallel to the zone-axis, and are opposed to quartz in the same direction. Cleavage flakes perpendicular to this zone-axis are seen, when viewed in parallel polarised light, to consist of three portions, which extinguish at angles of 60° to each other; each portion shows a very finely striated appearance (suggesting the intergrowth of two substances), extinction taking place parallel to the striations. Only rarely could portions of a positive uniaxial figure be distinguished. The refractive index was determined with a prism (bounded by *a* and *d* cleavage) from one of these crystals to be about $2\frac{1}{4}$ for the yellow part of the spectrum. Qualitative chemical tests showed the presence of silver and iodine with only a very small amount of copper; and fragments fused on a microscope slide show only a few of the isotropic bars. These crystals, therefore, appear to consist of an intimate and regular intergrowth of miersite and iodyrite. The nature of this intergrowth is suggested by the iodyrite crystals of type (*b*) (Fig. 1) described below.

Summarising the above observations, miersite may be defined as an optically isotropic, tetrahedral-cubic mineral, of which the composition is

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probably 4AgI.CuI, and which mixes isomorphously with marshite (CuI) on the one hand, and on the other forms intimate intergrowths with iodyrite.

Possible identities.—When isomorphously mixed with a certain amount of marshite, the composition would become identical with that of "cuproiodargyrite" (AgI.CuI). This mineral, from Iquique in Chili, is stated[1] to be brighter in colour and lustre, and to be harder and less sectile than iodyrite; the fracture is given as sub-conchoidal to splintery. These characters, so far as they go, agree better with those of miersite than with those of iodyrite, and it seems probable that "cuproiodargyrite" is intermediate between miersite and marshite, and not, as the name[2] suggests, a cupriferous variety of iodyrite.

Another mineral which may be mentioned here is the silver iodide from Chili, examined by Lawrence Smith.[3] His two analyses of "an exceedingly pure specimen" showed the presence of traces of copper and chlorine; and he states: "One specimen that I saw had crystalline faces, indicative of the rhombic dodecahedron." It is therefore possible that the material he examined may have been iodyrite intergrown with miersite. The silver iodide described by Domeyko[4] also seemed to differ from iodyrite in being brittle and in sometimes giving "cleavage fragments with rhombohedral forms."

III. Iodyrite.

Occurrence: Physical Characters.—The occurrence of iodyrite at Broken Hill is well known, but as yet no crystallographic description has been given. The several specimens from this locality in the British Museum collection show two distinct modes of occurrence:

(1) Pale sulphur-yellow crystallised material on a free surface often consisting of limonite or psilomelane; associated minerals are brown garnets, blue opalescent quartz, malachite, cerussite, cuprite, pyromorphite, anglesite, calamine ($ZnCO_3$), chessylite, or wad.

(2) Films or thin layers, of a rather brighter colour, on the surfaces of slickensides in white kaolin. They often show green stains, but the pure material free from these stains contains no copper.

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[1] H. Schulze, Chemiker-Zeitung, 1892, XVI, 1952.

[2] Names of a similar construction are, however, frequently admitted into mineralogical nomenclature as species rather than as variety names, e.g. barytocalcite, cuprobismutite, galenobismutite, arsenopyrite, etc.

[3] Amer. Journ. Sci. 1854 [ii.] XVIII, p. 374; U. S. Naval Astronomical Expedition to the Southern Hemisphere (1849-52), Vol. II, 1855, p. 96.

[4] Annales des Mines, 1844, [iv], VI, p. 158.

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The mineral is very soft (H about 1, or perhaps less) and sectile, so much so that the crystals can scarcely be touched without suffering distortion. The fracture is conchoidal, and the perfect basal cleavage shows a pearly lustre. Sometimes in freshly opened cavities the crystals are perfectly colourless and transparent with an adamantine lustre; they then somewhat resemble crystals of anglesite in appearance. On exposure to light the colourless crystals very soon assume the usual pale sulphur-yellow colour of iodyrite, and this is not further altered by prolonged exposure to bright sunlight. The streak is rather brighter yellow in colour with a tinge of green; it is shining and easily flakes off the paper.

Optically the mineral is uniaxial, with low positive double refraction. The tabular crystals and cleavage flakes, being so easily bent, usually show undulose extinction in parallel light, and in convergent light the optic figure is often distorted, sometimes resembling a biaxial figure; as a cleavage flake is moved about on the microscope stage the interference figure continually varies. Attempts to produce corrosion and percussion figures on the cleavage flakes were unsuccessful, and on none of the crystals could any pyroelectrical effects be detected.

The physical characters of iodyrite are considerably modified by the presence of a small amount of copper iodide: as explained above (p. 44) this copper may be assumed to be present as 4AgI.CuI (miersite) occurring as an intimate intergrowth with the iodyrite.

Crystallographic characters.—Several crystals were measured on the goniometer, but no reliable determinations of the angles could be made, as few faces are developed, and the crystals are so easily distorted. The crystals are of two distinct types:

(*a*) Hexagonal plates or short prisms, with the forms $c\{111\}$, $m\{2\bar{1}\bar{1}\}$, and sometimes a narrow hexagonal pyramid near the position of $i\{5\bar{1}\bar{1}, \bar{1}11\} = 2P$, if placed as a pyramid of the first order. The prism and pyramid faces are usually striated horizontally. On one specimen the prisms are 1½ cms. in diameter. On none of these crystals was a hemimorphic development observed.

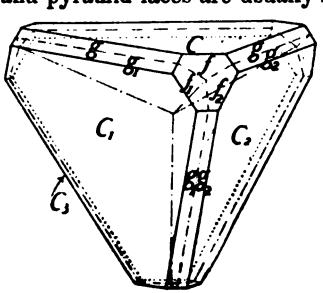

Fig. 1.

(*b*) Pseudo-cubic crystals, of tetrahedral habit, consisting of four simple rhombohedral crystals twinned together. Fig. 1 shows a compound crystal, and Fig. 2 the uppermost of the four simple crystals drawn in parallel position. These crystals cannot be distinguished by gonio-

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metric measurement from marshite and miersite: they are in fact mimetic crystals of iodyrite with the same external form as miersite and marshite.

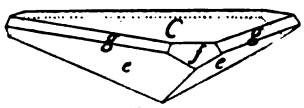

FIG. 2.

The twin-plane $e\{10.1.1\}$[1] $=\frac{3}{4}R$, is the same as that given by vom Rath[2] in his description of iodyrite crystals from New Mexico. He mentioned that three individuals were often arranged around a central one, but in these crystals, since the predominating form was $i\{\bar{1}11\} = -2R$, the twinning was rendered evident by the presence of re-entrant angles. In the crystals now described, $c\{111\}$ predominates in the compound crystal and corresponds to the regular tetrahedron. The smaller faces of $g\{55\bar{4}\} = -\frac{3}{4}R$ and $f\{7\bar{2}\bar{2}\} = 3R$ correspond to the faces of the cube and the second tetrahedron respectively, two faces of g and three of f coming together. These compound crystals therefore show no re-entrant angles.

The angles measured on these pseudo-cubic crystals were not really good, but they agreed closely with the angles of cubic crystals. It is to be noted that the angles determined by von Zepharovich on artificial crystals of iodyrite vary slightly in one direction from cubic angles, while the measurements of Des Cloizeaux and of Seligmann[3] on natural crystals vary slightly on the other side of cubic angles; this is shown in the table below:

	Seligmann.	Cubic angles.	Zepharovich.
$c : e\{10.1.1\} = \frac{3}{4}R$	35°14′	$od =$ 35°16′	35°22′
$c : g\{55\bar{4}\} = -\frac{3}{4}R$	54°42′	$oa =$ 54°44′	54°50′
$c : f\{7\bar{2}\bar{2}\} = 3R$	70°30½′	$oo =$ 70°32′	70°36′
$c : c_1$	109°32′	$oo =$ 109°28′	109°16′
$g : g_1$	Salient 8′	0°	Re-entrant 24′

The compound nature of the crystals is very well shown by the examination in polarised light of cleavage flakes taken parallel to the faces of the pseudo-tetrahedron. In parallel light these show a dark equilateral triangle surrounded by narrow areas extinguishing parallel to the sides of the triangle and opposed to quartz in the same direction. In convergent

[1] The indices are much simplified if g be taken as $(100) = R$; the twin-plane then becomes (110).

[2] F. A. Genth and G. vom Rath, Zeits. Kryst, Min., 1885, X, 473.

[3] Zeits. Kryst. Min. 1882, VI, 229.

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light the triangular portion shows in the centre of the field the usual positive uniaxial figure of iodyrite, while the borders show uniaxial brushes belonging to an axis outside the field of view. Usually, however, this structure is polysynthetic, and the same fragment may show, in parallel polarised light, several dark triangular areas and numerous lamellæ in three sets, each set of which extinguish together throughout the whole fragment.

These compound crystals of iodyrite are further twinned on a face, or sometimes on two faces, of the pseudo-tetrahedron, exactly like the crystals of marshite and miersite. As a consequence of this, re-entrant angles of about 15°48′ ($=o\bar{a}$)[1] are frequent, and the narrow faces corresponding to the cube are deeply furrowed and striated. On account of this deep striation it was not possible to determine whether the very small angle yy_1 (Fig. 1) is re-entrant or salient, and thus to decide whether the angles of Zepharovich or of Seligmann come nearer the truth.[2]

The pseudo-cubic crystals of iodyrite of type (*b*) differ essentially from the pseudo-cubic crystals of stannite described in this number of the Magazine (p. 56); these also are twinned on a pseudo-tetrahedron face. The iodyrite crystals were originally true cubic crystals, but are now paramorphs of iodyrite after the tetrahedral-cubic modification of silver iodide. Here the twinning is the result of the pseudo-cubic symmetry, whereas in stannite the twinning is clearly the cause of the pseudo-cubic symmetry. The case of iodyrite is similar to that of many cubic minerals showing optical anomalies which disappear at a higher temperature, *e.g.* boracite, leucite, cristobalite, etc. In the case of iodyrite, however, the two kinds of crystals are known to occur independently. The iodyrite crystals of type (*a*) must have been formed at a temperature below 146° (assuming atmospheric pressure), while those of type (*b*) were formed above this temperature. It may be noted that the structure of the compound crystals of iodyrite (Fig. 1, p. 46) is identical with that of crystals of eulytite described by Bertrand,[3] and more fully, with figures, by Professor Lewis.[4]

[1] If *f* and *g* are present in the same zone [$2\bar{1}\bar{1}$, 111] or [$10\bar{1}$, 111] the angle $fg_1 = 16°10'$ or 15°30½′, according as the angles of Zepharovich or of Seligmann are taken.

[2] A consideration of the fact that the *c* axis of iodyrite contracts with rise of temperature before the passage into the cubic modification takes place, suggests that Zepharovich's angles are the more accurate, since with increase in temperature they will gradually approach those of cubic crystals.

[3] Bull. Soc. Min. de France, 1881, IV, 61: compare, however, R. Brauns, Die optischen Anomalien der Krystalle, 1891, p. 333.

[4] Treatise on Crystallography, Cambridge, 1899, p. 478.

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Behaviour when heated.—The change in state which silver iodide undergoes at a temperature of about 146° C. is well known. Talbot (1838)[1] first observed that when a film of silver iodide is warmed, its colour changes from pale sulphur-yellow to bright yellow; and various observers[2] have since shown that the pale yellow variety, which exists at ordinary temperatures, is birefringent and hexagonal, and that with an increase of temperature these crystals undergo a contraction in the direction of the hexagonal axis and an expansion in the directions perpendicular to this axis, while the total volume of the crystal diminishes. When the temperature reaches about 146° C., there is a further sudden contraction of considerable amount accompanied by a change in colour, thermal capacity, electrical conductivity and optical refraction—a denser, cubic and isotropic modification of silver iodide being then called into existence. The same change also takes place at the ordinary temperature, under a pressure of about 3000 kilos per sq. cm. These changes are reversible: on diminution of temperature or pressure the pale yellow hexagonal modification again appears.

When a cleavage plate of iodyrite is heated on a microscope slide there is, at a definite temperature, a sudden change from the pale yellow colour to a bright orange-yellow, and at the same time the plate becomes optically isotropic. On cooling, the pale yellow colour suddenly reappears, and the plate is seen, between crossed nicols in parallel light, to become birefringent. The plate, after being heated above this critical temperature, is cloudy, and no longer shows the perfect cleavage nor the uniaxial optic figure, since it now consists of an aggregate of differently orientated crystals of iodyrite.

At a still higher temperature the colour becomes brick-red, and the substance fuses to a deep-red liquid which is almost black by reflected light and which spreads out as a film under the cover-glass. On cooling again, the mass remains isotropic, while the colour gradually changes from brick-red to bright yellow; then follows a sudden change to the pale yellow birefringent modification, and the line of demarcation between the two can be seen to sweep quickly across the field of view. The slide then shows an aggregate of interlocking lath-shaped crystals, often of considerable size and showing brilliant polarisation colours. The longer direction

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[1] H. F. Talbot, Phil. Mag. 1838, XII, 258.

[2] Fizeau (1867), Wernieke (1871), Rodwell (1874, 1876), Lehmann (1877), Bellati and Romanese (1882), Kohlrausch (1882), Mallard and Le Chatelier (1883-5), Schwarz (1892).

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of the laths is perpendicular to the principal axis of the iodyrite crystals. With the aid of a micro-spectroscope the change in state on cooling is seen to be accompanied by a sudden increase in the length of the blue end of the spectrum.

IV. Mutual and other Relations.

As explained above, marshite and tetrahedral-cubic silver iodide are isomorphous. The latter when pure is only stable at a temperature higher than 146°, but when it contains a certain amount of copper (5·6 per cent. would be required by the formula 4AgI.CuI) it is stable at ordinary temperatures, and is then distinctive enough to receive the special name miersite. Larger amounts of copper may be present as an isomorphous mixture of marshite; while any excess of silver iodide will, at the ordinary temperature, be represented as iodyrite intimately intergrown with the miersite.

Silver iodide appears to exist also in a third form and therefore to be trimorphous. This is holohedral-cubic and isomorphous with members of the cerargyrite group. It is represented by the AgI in iodobromite (2AgCl.2AgBr.AgI), and as smaller amounts in cerargyrite, embolite and bromargyrite. It may here be mentioned that a mineral[1] similar to *iodobromite* occurs at Broken Hill in New South Wales and at Chañarcillo in Chili. At both these localities it is usually associated with iodyrite, and consists of cubo-octahedra of a bright orange-yellow colour, which soon alters to dark green on exposure to light. The crystals are translucent, and are so tough and sectile that fragments cannot be detached for optical examination without distortion: H = 2½. There is no distinct cleavage. Chemical tests showed the presence of silver, iodine, bromine and chlorine, all in considerable amount.

The characters of the three modifications may be compared in the following table:

	Iodyrite.	Miersite.	Iodobromite.
System	Rhombohedral	Cubic	Cubic
Class	Hemimorphic	Tetrahedral	Holohedral
Twin-plane	A Rhombohedral face	A tetrahedral face	Not twinned
Cleavage	Perfect basal	Perfect dodecahedral	Indistinct octahedral?
Optically	Uniaxial	Isotropic	Optically anomalous?
	$cg = 54°42'$ or $54°50'$	$oa = 54°44'$	$oa = 54°44'$

[1] An analysis and detailed description of this will be published later. The mineral from Chili was long ago described as cubic silver iodide, by A. Dufrénoy, Traité de Minéralogie, 2nd Edit., 1856, Vol. III. pp. 452, 460.

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Really, however, these three modifications of silver iodide only exist as minerals in isomorphous mixtures influenced by the mass effect of other substances, or in definite molecular compounds. They may or may not be identical with the three modifications mentioned by G. F. Rodwell.[1]

The possible existence of two cubic modifications of a compound containing silver iodide has also been suggested above (p. 44) from the behaviour of mixtures of silver iodide and copper iodide when heated. They are also possibly related to the two cubic modifications of mixed crystals of ammonium chloride, bromide and iodide produced by O. Lehmann[2]; these are, however, not beyond doubt, as pointed out by Arzruni.[3]

Lehmann[4] has stated that the cubic modification of silver iodide which is stable above 146° crystallises in octahedra and is isomorphous with cerargyrite: from the present observations, however, it would seem to be the tetrahedral-cubic modification isomorphous with marshite which crystallises out above this temperature.

As mentioned above (p. 47) there is a close connection between the angles of iodyrite and the angles of a cubic crystal; and between miersite and iodyrite there is a still further similarity in the development of the crystals. Some crystals of miersite have the habit of hemimorphic-rhombohedral crystals of iodyrite, while in iodyrite of type (*b*) the habit is identical with that of miersite. These close relations indicate that there must be similarity in crystalline structure,[5] as is often the case with dimorphous minerals, for example, zinc-blende and wurtzite, orthoclase and microcline. In such cases Mallard[6] has suggested the essential identity of these pairs of minerals, the one of higher symmetry being the result of ultra-microscopic twinning of the one of lower symmetry. In the same way crystals of iodyrite of type (*b*) might by repeated twinning give rise to isotropic crystals identical with miersite; but here, as in the case of zinc-blende, the perfect rhombic-dodecahedral cleavage would be difficult to explain, unless it were a parting parallel to the twin-planes *e* of iodyrite, which, in the compound crystals, coincide in direction with the faces of the rhombic-dodecahedron.

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[1] Proc. Roy. Soc. 1874, XXIII, 108; Phil. Trans. 1883 (1882), CLXXIII, 1134.

[2] Zeits. Kryst. Min. 1885, X, 321; "Molekularphysik," 1888, I, 792.

[3] Physik. Chemie d. Krystalle, 1893, p. 321.

[4] Zeits. Kryst. Min. 1877, I, 492; "Molekularphysik," 1888, I, 166.

[5] Related kinds of groupings of the atoms of silver iodide in the rhombohedral and cubic modifications have been suggested by Prof. W. J. Sollas, Proc. Roy. Soc. 1898, LXIII, 289.

[6] Bull. Soc. Min. de France, 1882, V, 325; Ann. des Mines, 1876, [vii], X, 157.

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When crystals of iodyrite were first described by Des Cloizeaux, he noticed that in the angles there was a very close relation to greenockite. This relation may also be extended to other mineral species, as shown in the following table:

			$a : c$	Cleavage.
Iodyrite.....	AgI	Hemimorphic-rhombohedral. Optically+	1 : 0·8196	*c* perfect
Wurtzite	ZnS		1 : 0·8175	*a* *c*
Greenockite	CdS		1 : 0·8109	*a* *c*
Zincite	ZnO		1 : 0·8109	*c* perfect

These minerals are placed by F. Rinne[1] in the "magnesium type" of his isotypes: other members are magnesium ($c = 0{\cdot}8195$), niccolite ($c = 0{\cdot}8194$), ice ($c = 0\ 8085$), tridymite ($c = 0{\cdot}8265$), lead iodide ($c = 0{\cdot}8379$), and many others, all of which are chemically simple substances. Some of these are dimorphous, and form another parallel series:

Miersite	(Ag,Cu) I	Tetrahedral-cubic. Twinned on a tetrahedron face. Perfect dodecahedral cleavage.
Zinc-blende	Zn S	
Marshite.....	Cu I	

Nantokite[2] (CuCl) probably belongs to this series. Numerous other substances crystallise in both cubic and rhombohedral modifications (*e.g.* carbon as diamond and graphite), but they do not appear to belong to these series.

Now it will be seen from the above tables that the same relation exists between iodyrite and miersite as exists between wurtzite and zinc-blende:

Hemimorphic-rhombohedral.	Tetrahedral-cubic.	Holohedral-cubic.
Iodyrite	Miersite	Iodobromite
Wurtzite	Zinc-blende	(Schalenblende) ?

As far as crystallographic characters are concerned this is a perfect example of an isodimorphous (perhaps isotrimorphous) group, but

[1] Neues Jahrb. Min. 1894, I, 1; 1897, II, 1; Zeits. physik. Chemie, 1895, XVI, 529.

[2] The cubic cleavage given by Breithaupt requires verification.

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apparently the only chemical relation existing between zinc sulphide and silver iodide is that their simplest conceivable molecules contain two atoms. Isomorphous replacement[1] does not occur, and no apparent relation is shown by the molecular volumes. Isomorphous replacement, however, takes place between miersite and marshite, and between iodobromite and cerargyrite; in the former between the metals, and in the latter between the haloids.

[1] Mentzel has found iodine in a cadmiferous zinc ore from Silesia. Ann. des Mines, 1829 [ii], V, 324; *cf.* Dana, System of Mineralogy, 6th Edit. 1892, p. 161.

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Crystallised Stannite from Bolivia.

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(With Plate II.)

[Read November 14th, 1899.]

Historical and Introductory.

VERY little is known of the crystalline form of the somewhat rare mineral stannite, since in the few localities in which it has been found it usually occurs only in the massive state. Several suggestions, summarised below, have been made as to the type of crystalline symmetry of the mineral, but hitherto no crystals have been completely examined.

(1) *Orthorhombic.* Haüy (1822)[1], from an examination of cleavage fragments from Cornwall, concluded that the primitive form might possibly be a right rhombic prism.

(2) *Cubic.* Haidinger (1825)[2] mentioned Cornish crystals, having apparently the form of regular cubes, but the dulness of the faces did not allow of any measurements. The massive material appeared to show cleavages in the directions of the faces of the cube and rhombic dodecahedron. (Crystals of Cornish stannite are further mentioned on p. 65 below.)

(3) *Tetrahedral-Cubic.* Stannite has often been assumed to be a stanniferous fahlerz, and consequently to have the same crystalline form. It appears to have been Breithaupt (1830)[3] who first placed stannite in this systematic position, and assigned to it this type of symmetry.

Later, Breithaupt (1866)[4] mentioned large triakistetrahedra from Peru,

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[1] Traité de Minéralogie, 2nd Edit. 1822, Vol. IV, p. 170.

[2] English translation of Mohs' Mineralogy, 1825, Vol. III, p. 163.

[3] Uibersicht des Mineral-Systems, 1830, p. 75. Vollständige Char. d. Mineral-Systems, 3rd Edit. 1832, p. 275.

[4] Berg- und hüttenmänn Zeitung, 1866, XXV, 181; and Min. Studien, 1866, p. 102

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but these have since been shown[1] to be only tetrahedrite. In 1884 vom Rath[2] mentioned a similar large crystal, also from Peru, as existing in the collection of Mr. C. S. Bement, of Philadelphia. While on a visit to London, in December, 1899, Mr. Bement informed me that this crystal is very indistinct, and that it is no longer considered to be stannite.

More recently Stelzner[3] has described crystallised stannite from Potosi, Bolivia. The crystals are 5 mm. across and show the cubic forms $+o\{111\}$ and $-o\{1\bar{1}1\}$, with subordinate $d\{110\}$, $a\{100\}$ and $\kappa\{hkk\}$, but goniometric measurements do not appear to have been made. The crystals gave the blowpipe reactions of stannite, and a quantitative chemical analysis was made of the accompanying massive material. These crystals, which are the most distinct yet described, are stated by Stelzner to be frequently built up of sub-individuals: this suggests that they are probably only pseudo-cubic, and like the crystals to be described in the present paper.

(4) *Scalenohedral-Tetragonal.* Kenngott (1849)[4] considered stannite to be a stanniferous copper-pyrites, and remarked that Haidinger's cubes could equally well be considered to be tetragonal with the same symmetry as copper-pyrites. This view was supported by Delafosse.[5]

Of these types of symmetry the third—tetrahedral-cubic—is the one now generally accepted for the mineral. It will, however, be shown below that the crystals really belong to the fourth type, namely scalenohedral-tetragonal, but that by twinning the symmetry becomes pseudo-tetrahedral-cubic.

The specimen (Brit. Mus. No. 84686) which supplied crystals for the present investigation is from the San José Mine at Oruro, Bolivia; it was obtained by Sir W. Martin Conway, while on his Bolivian Expedition in 1898, and was, with several other Bolivian specimens,[6] presented by

[1] A. W. Stelzner, Zeits. Deutsch. geol. Ges. 1897, XLIX, 75; and Dana's System of Mineralogy, 6th Edit. 1892, p. 83.

[2] Verh. Ver. Rheinl. Bonn, 1884, XLI, 296; Compare A. W. Stelzner, Zeits. Deutsch. geol. Ges. 1897, XLIX, 75.

[3] Zeits. Deutsch. geol. Ges. 1897, XLIX, pp. 97, 131; abstract Min. Mag. 1898, XII, 46. Stelzner's crystals were first mentioned in Zeits. Deutsch. geol. Ges. 1892, XLIV, 531; abstract Min. Mag. 1893, X, 261.

[4] Min. Untersuchungen, 1849, I, p. 41; Kenngott's Uebersicht (1844-9), 1852, p. 237.

[5] Nouveau Cours de Minéralogie, 1860, II, 416.

[6] An account of this collection will be published as an Appendix to Sir Martin Conway's book, "Bolivian Andes."

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him to the British Museum. This specimen consists of radiating groups of prismatic crystals of mispickel, on which are a few bright crystals of andorite and pyrites. Encrusting all these minerals is the stannite, which occurs abundantly as crystalline crusts and as isolated crystals. As a later encrustation are minute white globules of an undetermined mineral.

The occurrence of crystallised stannite at Oruro has been previously mentioned by d'Orbigny [1] but the only information given by him is: "On n'exploite à Oruro qu'un riche filon d'étain du sommet de la montagne; filon composé d'étain sulfuré presque pure, souvent cristallisé."

Crystallography.

The crystals average 1—1·5 mm. across; the largest is 3 mm. Many of them are irregularly aggregated in crusts and partly embedded, and are consequently difficult to decipher, but those which are more isolated show very distinctly the form illustrated in Fig. 3, Plate II. They have the appearance of cubic crystals, but on closer examination they are at once seen to be composite. The faces are usually striated and rough, and on the goniometer they give several scattered images. A first series of approximate measurements was not good enough to distinguish the angles from those of a cubic crystal, but at the same time it was observed that the striations and characters of the faces agree only with scalenohedral-tetragonal symmetry. A second series of measurements carefully made on the best crystals, however, showed that the angles also agree with tetragonal and not with cubic symmetry.

The inclined hemihedral (scalenohedral) character is not a striking feature, and was not at first noticed,[2] but when the crystals are examined closely the differences in adjacent octants may easily be seen (Figs. 1—4). In one set of (positive) octants the planes of $p\{111\}$ and $n\{211\}$ are bright and smooth and the edges sharp, while in the adjacent (negative) octants p and n are represented by rather larger faces, which are here rough. The faces of n being larger cause the pits (Fig. 3) in the negative octants to be shallower, owing to the exclusion in many cases of the faces of $c\{001\}$.

[1] Voyage dans l'Amérique méridionale, 1826—1833, Tome III, 3e Partie, Géologie, p. 129, 1842. Stelzner (*loc. cit.* p. 86) has doubted this occurrence, but without sufficient reason.

[2] The figures prepared for the preliminary account in Sir Martin Conway's book, "Bolivian Andes," represent the crystals as holohedral.

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The forms[1] noticed on the crystals measured are given below; with the exception of *a d t u* they are well developed on all crystals.

c{001}. Bright and smooth. On crystals which are in part simple it is present as a rather large face (Fig. 1), but in the twinned groups it is only present as small faces, forming the deep pits (Fig. 3).

a{100}. Usually only represented by striæ on *z*{201}, but on crystals from one specimen (described on p. 64 below) it is present as a bright narrow face on the edge [*zz*].

m{110}. Bright, but usually deeply striated, owing to its oscillation with $+p\{111\}$ and $-p\{1\bar{1}1\}$. The twinning makes this the most prominent face on the crystals.

e{101}. Bright; striated horizontally.

z{201}. Deeply striated horizontally, the striæ reflecting light with *e*{101} and *a*{100}.

$+d\{114\}$. Very narrow planes on the edge between $+n$ and *c*; deeply striated parallel to this edge. Other reflections from striæ were obtained near the positions of {229} and {223} also in the positive octants.

$+n\{112\}$. Bright and smooth; small.

$+p\{111\}$. Bright and smooth; small. This and $+n$ are faintly striated parallel to their mutual intersection.

$+t\{221\}$. Observed only once as a very narrow striation on the edge $[+p,m]$.

$-n\{1\bar{1}2\}$. Dull and rough; rather larger than $+n$.

$-p\{1\bar{1}1\}$. Dull and rough; usually rather larger than $-p$, but sometimes quite small.

$+u\{423\}$. Minute bright faces in the zone [201, 111, 021]. On two crystals.

About a dozen crystals were measured on the goniometer, but reliable measurements could be obtained from only a few. Only portions of simple crystals can be observed, and it is not always easy to separate the reflections belonging to each individual. Even portions of crystals, which

[1] The letters adopted for the forms are those used in Dana's Mineralogy (6th Ed. 1892) for copper-pyrites. For these forms to be strictly analogous with those of copper-pyrites + and — would probably have to be interchanged.

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are at first sight apparently simple, were usually found on more careful examination to show twin-lamellæ. The results of the measurements are:

	Measured.	Limits.	No. of edges.	Calculated.	Copper-pyrites (Haidinger).	Corresponding Cubic angles.
$ce = 001 : 101$	*44° 30′	42°24′ — 44°38′	10	—	44° 34½′	45° 0′
$cz = 001 : 201$	63 8	62 57 — 63 15	7	63° 2′	63 5½	63 26
$cd = 001 : 114$	19 9	18 — 20	8	19 9½	19 12½	19 28
$cn = 001 : 112$	34 44	34 16 — 35 4	9	34 48	34 52	35 16
$cp = 001 : 111$	54 15	54 1 — 54 38	19	54 16	54 20	54 44
$cm = 001 : 110$	89 57	89 54 — 90 2	9	90 0	90 0	90 0
$tp = 221 : 111$	16	—	1	15 57	15 55½	15 47½
$en = 101 : 112$	29 46	29 41 — 29 52	4	29 42½	29 45	30 0
$ee' = 101 : 011$	59 35	59 30 — 59 40	2	59 25	59 30	60 0
$em = 101 : 110$	60 7	60 5 — 60 8	4	60 17½	60 15	60 0
$pu = 111 : 423$	15 11	15 0 — 15 18	3	15 8½	15 9	15 13½
$mm' = 110 : 110$	90 0	89 58 — 90 5	5	90 0	90 0	90 0

Twinning.—The most interesting feature of the crystals is the twinning, which gives rise to pseudo-cubic forms, and is invariably present. The two twin-laws are:—

(i) Interpenetrant symmetric twins with $e(101)$ as twin-plane, the two individuals being symmetrical to each other with respect to this plane.

(ii) Interpenetrant twins with the twin-axis perpendicular to $p(111)$ Also juxtaposed twins (Fig. 4) with the same twin-axis and $p(111)$ for the plane of combination.

The first law, on which every crystal is twinned, is illustrated by Figs. 2 and 3, and the stereographic projection, Fig. 5. The ideal simple crystal (Fig. 1), when reflected across the plane (011), gives the interpenetrating doublet shown in Fig. 2, and when also reflected across the homologous plane (101) the three interpenetrating individuals produce a figure closely resembling a regular rhombic dodecahedron in appearance (Fig. 3). In each octant three planes of the tetragonal sphenoid $p\{111\}$ come together, and correspond to the regular tetrahedron; these faces bound the edges of deep triangular pits formed by three faces of $n\{112\}$ and three faces of the basal planes $c\{001\}$, the latter being in the twinned position approximately parallel to the three faces of the cube. The prism

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faces $m\{110\}$ of the simple crystals form the faces of the pseudo-dodecahedron, the edges of which are replaced by V-shaped grooves formed by the faces of $e\{101\}$. Owing to a frequent oscillation between $e\{101\}$ and $:\{201\}$, these grooves gradually widen out towards the pseudo-tetrad axes. Each pseudo-dodecahedral face m is very nearly parallel to four portions of two e faces in the opposite sides of the four grooves adjacent to it. The striations on these planes m and e, which are nearly parallel, and sometimes in the actual crystals nearly co-planar, are approximately at right-angles (really 90°42½′); and it was this character which suggested in the first place that the crystals could not be parallel groupings of cubic sub-individuals. Doublets resembling Fig. 2 are rarely present on the specimen, and there are always indications of a third individual. Crystals like Fig. 3 are common, and are often as symmetrically and regularly developed as shown in the drawing; in some cases they are developed on nearly all sides, one crystal showing six of the eight possible triangular pits. From the projection (Fig. 5)[1] it will be seen that in the two opposite octants XYZ and $\bar{X}\bar{Y}\bar{Z}$ the sphenoidal planes $p\{111\}$ of the three individuals are coincident, while in the two octants $\bar{X}\bar{Y}Z$ and $XY\bar{Z}$ all three planes of $p\{111\}$ are separate; in each of the remaining four octants two sphenoidal planes coincide and the third is separate. Each pole m of the pseudo-dodecahedron nearly coincides with two poles e, except in the positions (101) and (011) where there is only one pole e. Although approximating to cubic symmetry, it will be seen from the projection that there is only one plane of symmetry to the whole group of three crystals.

The following (p. 60) are the observed and calculated (from $ce = 44°30'$) angles, when the crystals are twinned on $e(101)$ and (011).

These measured and calculated angles are not in close agreement. The images were often scattered, and not very good; further, it was not always possible to distinguish to which individuals the various reflections belonged, especially when the crystals are further complicated by twinning on the second law.

It was not possible to distinguish between $c\bar{c}$ (or cc) and $\bar{c}\bar{c}$, or between $p\bar{p}$ (or pp) and $\bar{p}\bar{p}$. Only on one crystal could more than one of the

[1] The angle ce in the projection has been taken as 43½°, instead of 44½°, in order to separate more distinctly the poles which nearly coincide. The poles of the crystal in the normal position are indicated by unbarred letters, those of the crystal twinned about (101) are indicated as $\bar{c}\bar{e}$, etc., and those twinned about (011) as $c\bar{e}$, etc. The parallel planes beneath the plane of projection are omitted.

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	Calculated.	Measured.
$p\bar{p}=p\underline{p}$	1° 38½′	1°29′, 1°29′, 1°24′, 1°10′, 1°10′, 1°6′, 1°5′, 53′, 35′.
$\underline{p}\bar{p}$	1 37½	
$c\bar{c}=c\underline{c}$	89 0	Numerous readings between the limits 89°11′ and 90°33′.
	91 0	
$\underline{c}\bar{c}$	89 59	
$m\underline{e}=\bar{m}e=$etc.	0 52	
$e\bar{e}=\underline{e}\underline{e}$	2 0	
$\underline{e}\bar{e}$	1 25½	1°27′.

angles $p\bar{p}$, etc., in the same octant be fairly accurately measured: the results were 1°10′ and 1°6′. In the same pit the angles between the three planes of $c\{001\}$ were measured as 90°33′, 90°30′, 90°22′, and in another pit as 90°32′, 90°26′, 90°12′. The portions of the planes of $c\{001\}$ in adjacent octants are never quite parallel, the angles 48′, 25′, 20′, etc. being measured; even apparently single c planes in the same octant sometimes give two sharp images measured at 21′, 22′, etc. apart.

Twinning on the second law, in which the twin-axis is (111), though common, is not invariably present, as is twinning on the first law. The pseudo-dodecahedra (Fig. 8) described above give rise to the juxtaposed twin shown in Fig. 4, or two interpenetrate.[1] Twin lamellæ may also often be seen running through the crystals. As shown in Fig. 4, these are not symmetric twins as in the first law.

The calculation of the angles of crystals twinned on the second law is much simplified if it is assumed that the three twin-planes (101), (011) and (111) all have positive indices[2]; the twin-plane (111) will then be exactly coincident for all three simple individuals, and the twin-axis will be strictly parallel to the zone-axis of the pseudo-hexagonal zone formed by six m planes. Several planes of $e\{101\}$ will be slightly out of this pseudo-hexagonal zone, and when twinned on (111) they will form with each other across this zone angles of 1°38½′; the corresponding measured values were 1°13′ and 1°10′. The prominent striations on the m faces make, in the twin crystals (Fig. 4), an angle of 108°31½′. It was not, however, possible to prove that the four twin-planes all have positive

[1] Compare the interpenetrating dodecahedra of argyrodite figured in Min. Mag. 1898, XII, 7.

[2] In Fig. 4 the twin-plane is $(\bar{1}11)$.

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indices, and it is quite possible that another combination of homologous planes might account for the irregularities between the measured and calculated angles noted above.

The pseudo-cubic groups described above remind one of the pseudo-dodecahedra of phillipsite, and also of the several cubic minerals exhibiting optical anomalies; but in these cases the groupings are usually more complex than the twinning together of three tetragonal individuals.[1]

Physical Characters.

The colour of the stannite crystals is iron-black, with a bright metallic to sub-adamantine lustre, somewhat resembling black blende. On one specimen (described below) the crystals have a bronze-coloured tarnish on the surface. The mineral is opaque. The streak is black and dull. The crystals are not very brittle; H = 3½. The fracture is sub-conchoidal to uneven; no cleavage was observed.[2] Specific gravity 4·45.[3]

Chemical Composition.

The material collected for analysis consisted mainly of well-developed crystals projecting from the surface of the specimen, but some of the underlying crystalline material was also collected in the belief that it was all stannite; the latter, however, contained some andorite, as suggested by the results of the analysis, and as actually seen to be the case upon a further and more careful examination of the specimen.

The results of the analyses by Mr. G. T. Prior are given below under columns I-V. Analysis I was made on 0·3678 gram of material, which was decomposed with nitric acid; in II, 0·4215 gram was fused with sodium carbonate and sulphur, and the tin obtained in solution as sodium sulpho-stannate; for the sulphur determination (III) 0·2233 gram was fused with sodium carbonate and potassium nitrate. The mean of these analyses is given under IV. Germanium was tested for, but found to be absent:—

	I.	II.	III.	IV(Mean).	Atomic ratios.
Cu ...	28·58	28·54		28·56	·453
Fe ...	10·95	10·90		10·93	·197
Sn ...	25·52	24·90		25·21	·213
Sb ..	3·54	3·88		3·71	·031
Pb ...	2·02	2·09		2·06	·010
Ag ...	0·94	0·82		0·88	·008
S ...	—	—	27·83	27·83	·874
				99·18	

[1] Compare the pseudo-cubic crystals of iodyrite described in this number of the Magazine, p. 46.

[2] Crystals of Cornish stannite appear to possess cleavages, see pp. 54, 65.

[3] Calculated from the specific gravity of the material analysed (4·52) by deducting 8·58 per cent. of andorite (sp. gr. 5·35).

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The atomic ratios of Sb, Pb and Ag are approximately those required by he andorite formula $PbAgSb_3S_6$; and the atomic ratios of Cu : Fe : Sn : remaining S = ·453 : ·197 : ·213 : ·814, agree approximately with the formula Cu_2FeSnS_4 for stannite. Under column V below is given the percentage composition of the stannite after deducting Sb_2S_3, PbS and Ag_2S. Column VI gives the calculated percentage composition required by the formula Cu_2FeSnS_4:—

	V.	VI(Cu_2FeSnS_4).
Cu ...	31·52 ...	29·54
Fe ...	12·06 ...	13·01
Sn ...	27·83 ...	27·65
S ...	28·59 ...	29·80
	100·00	100·00

This analysis, which is the first that has been made on crystallised stannite, therefore supports the empirical formula usually given for the mineral, namely Cu_2FeSnS_4.

This formula has been written by various authors in many different ways, of which only the following two need be mentioned here:—$Cu_4SnS_4 + Fe_2SnS_4$ represents an orthostannate, and $CuFeS_2 + CuSnS_2$ shows a possible relation to copper pyrites ($CuFeS_2$).

Relation between Stannite and Copper-pyrites.

The remarkably close crystallographic relation existing between stannite and copper-pyrites may now be pointed out. The type of symmetry—scalenohedral-tetragonal—is the same for both, and the angles are almost identical. The angular element (*ce*, 001 : 101 = 44°30′) given above for stannite lies between the usually accepted value for copper-pyrites, namely 44°34½′ (Haidinger), and that obtained by Mr. Fletcher[1] on crystals from Freiberg, Saxony, namely 44°22′. The crystal forms[2] and character of the faces are also similar. Further, the twin-laws[3] are the same, including the remarkable symmetric twins, of which very few examples are known among minerals. Pseudo-cubic crystals, as the

[1] Phil. Mag. 1882 [v], XIV, 287; Proc. Cryst. Soc. 1882, p. 126; Zeits. Kryst. Min. 1883, VII, 331.

[2] For the stannite forms to be strictly analogous with those of copper-pyrites + and — as given above, would probably have to be interchanged; if this is done all the stannite forms, with the exception of $-n\{1\bar{1}2\}$, have been noted on copper-pyrites.

[3] A third, but very rare, twin-law of copper-pyrites is represented by the complementary interpenetrant twins with $m(110)$ as twin-plane: this has not been observed on the stannite crystals.

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result of twinning, have long ago been figured by Haidinger[1] for copper-pyrites, and one of his figures represents a pseudo-cubic crystal again twinned on $p(111)$ as in Fig. 4 above.

As far as crystallographic characters are concerned stannite and copper-pyrites are therefore practically identical; and, as pointed out above, a possible chemical relation is suggested when the formula of stannite is written in the form $CuFeS_2 + CuSnS_2$ (that of copper-pyrites being $CuFeS_2$). There is absolutely no evidence to support the possible suggestion that the crystals described in the present paper may be pseudomorphs of stannite after copper-pyrites: the implanted crystals are quite sharp and homogeneous, and not a trace of copper-pyrites was seen on any of the Bolivian specimens.

The supposed relation (p. 54) between stannite and fahlerz receives some support in the fact that the composite twinned crystals of stannite simulate the symmetry of fahlerz.

Other Specimens of Crystallised Stannite.

Oruro, Bolivia.—Besides the specimen described above there are three others, brought by Sir Martin Conway from Oruro, on which are crystals of stannite. As the characters of the stannite and the associated minerals are somewhat different in each of these a brief description is now given.

The largest specimen (Brit. Mus. No. 84687) consists of a matrix of massive quartz, pyrites and tetrahedrite, with the free surface, measuring about 28×23 cm., covered with good crystals of augelite,[2] mispickel, quartz and pyrites, together with some powdery kaolinite and minute yellow globules of cervantite (?). On this surface are abundant drusy black crusts of stannite, but the form of the minute crystals cannot, as a rule, be made out even under the microscope. On parts of the specimen, however, where the stannite is more coarsely crystallised, the characteristic twinning described above can sometimes be distinguished. Small cavities at the back of the specimen contain good crystals of wolfsbergite,[3] andorite and stannite, the last like Fig. 3.

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[1] Memoirs Wernerian Nat. Hist. Soc. Edinburgh, 1822, Vol. IV, p 17, Figs. 37-41; Edinb. J. Sci. 1825, Vol. III, Plate III, Figs. 29, 32, 34. Two of Haidinger's figures are reproduced in Mr. Fletcher's paper (*loc. cit.*).

[2] This is the fourth locality at which the rare mineral augelite has been found. Compare Min. Mag. 1898, XII, p. 1.

[3] This is a new locality for the rare mineral, wolfsbergite (=chalcostibite). Compare Min. Mag. 1897, XI, 338. These occurrences are described in the Appendix to Sir Martin Conway's book, "Bolivian Andes."

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Another specimen (No. 84689) consists of an aggregate of jamesonite needles encrusted with small crystals of pyrites and stannite, the latter showing the complex twinning.

On the fourth specimen (No. 84684) some of the stannite crystals are of quite a different type. This is from the San José mine, and is a large piece of massive tetrahedrite with massive quartz and pyrites. One cavity is almost completely lined with crystals of stannite, which have a bronze coloured tarnish on the surface; they are about a millimeter across, and are confusedly grown together forming a crust. The faces are bright, and smoother than those of the crystals described above. Two of the partially embedded crystals were measured on the goniometer; each showed one large plane of the form $m\{110\}$, surrounded at the edges by smaller faces of $z\{201\}$, $a\{100\}$, $e\{101\}$ and $n\{112\}$. They are twinned on $p(111)$, one crystal being twinned on two planes of this form: no twinning on the plane $e(101)$ was detected on these crystals. Other cavities in this specimen contain black crystals of stannite, like those figured above, together with crystals of wolfsbergite, andorite, quartz and pyrites.

Potosi, Bolivia.—A small specimen (No. 84075) from this locality was supplied to the Museum in 1898 by Messrs. G. L. English and Co. of New York. It consists of massive quartz, pyrites and tetrahedrite, with crystals of quartz, mispickel and stannite in cavities. The stannite crystals are black with a brilliant metallic to sub-adamantine lustre; they are very small and closely aggregated together. On the goniometer only approximate measurements could be obtained; all that could be determined was a triangular face bounded at the edges by three narrow planes at angles of about $35\frac{1}{2}^{c}$ with the triangular face. The triangular faces gave two, three or more images (one pair at 48′ apart), but no pits, as shown in Fig. 3, were seen. The crystals are too imperfect to show whether they are pseudo-cubic, or cubic with the forms $o\{111\}$ and $d\{110\}$.

The association of minerals on this specimen is the same as on the specimen from Potosi described by Stelzner (p. 55), but his crystals of stannite were larger and probably more distinct.

Tatasi, Bolivia.—This specimen (No. 84324) from the Carmen vein in the silver mine at Tatasi, prov. Sud-Chichas, dept. Potosi, was presented to the Museum by my friend Mr. Malcolm Roberts, A.R.S.M., Administrator of Mines to the Compañia Guadalupe de Bolivia The matrix is a white, altered volcanic tuff with blebs of quartz and numerous veins and specks of pyrites. On the free surface are crystals of quartz, pyrites and stannite, the last being in very indistinct rounded crystals or groups

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of crystals, up to 3 mm. across, with a black drusy surface. The stannite encrusts pyrites, and sometimes there is only a shell of material enclosing pyrites. The most distinct crystal appears to be cubic with the form of a deltoid-dodecahedron $\kappa\{hhk\}$, and it further appears to show signs of being composite like the Oruro crystals described above.

Cornwall.—Only two of the several specimens of Cornish stannite in the British Museum show any signs of crystals; and these are similar to the imperfect crystals mentioned by Haidinger in 1825 (see p. 54 above). The specimens, which are labelled Cornwall (No. 19109) and Wheal Rock, St. Agnes (No. 33475), consist of compact granular stannite, showing in places indications of a poor cleavage; the colour is dark steel-grey, with a yellowish tinge owing to the presence of intermixed copper-pyrites. On the walls of cavities in the massive material are a few distorted cubes or short square prisms of stannite, which measure up to 2 mm. in cross-section; a few crystals are much elongated and measure $8 \times 1 \times 1$ mm. The faces of these crystals are very dull and uneven, and are encrusted with numerous minute crystals of copper-pyrites. Approximate measurements on the goniometer gave angles of about 90°. There appears to be a fair cleavage perpendicular to the length of the prism, and possibly another cleavage parallel to the faces of the prism. These crystals may therefore be tetragonal with the basal pinacoid and one prism. The colour of the crystals is the same as of the massive material, and the streak is dull black.

Crystals from all the specimens mentioned above were examined chemically by Mr. Prior, and in each case found to contain copper, iron, tin and sulphur.

EXPLANATION OF PLATE II.

Fig. 1.—An ideal simple, scalenohedral-tetragonal crystal of stannite, with the forms. $c\{001\}$, $m\{110\}$, $e\{101\}$, $z\{201\}$, $+p\{111\}$. $-p\{1\bar{1}1\}$, $+n\{112\}$, $-n\{1\bar{1}2\}$.

Fig. 2.—The same twinned on (011).

Fig. 3.—The same twinned on (011) and (101), producing a pseudo-cubic compound crystal.

Fig. 4.—A pseudo-cubic crystal, as in Fig. 3, further twinned on $p(\bar{1}11)$.

Fig. 5.—Stereographic projection of Fig. 3 (*see* footnote on p. 59).

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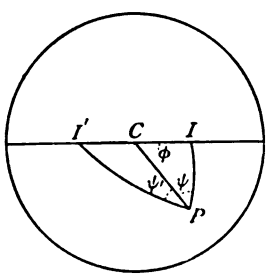
On a Question relative to Extinction-angles in Rock-slices.[1]

By Alfred Harker, M.A., F.G.S.

[Read January 22nd, 1901.]

MANY minerals of the rhombic system are of markedly columnar habit, with the axis of elongation, or vertical axis, as one of the bisectrices of the angles between the optic axes. Such a crystal, in a section parallel to the vertical axis, gives straight extinction. It is natural to expect, and is perhaps generally assumed, that a section slightly oblique to the vertical axis will give nearly straight extinction. The object of the present note is to inquire how far this is true, and in what possible cases a serious error may arise.

Let P in the figure be the pole of the plane of section; C, I, I' the points corresponding with the vertical axis and the two optic axes.



Let $CI = V = CI'$; $CP = \frac{\pi}{2} - \theta$, so that θ is the obliquity of the section; the angle $ICP = \phi$; and the angles CPI and $CPI' = \psi$ and ψ' respectively.

Then by solving the triangles CPI, CPI', we have—

$$\tan \psi = \frac{\sin V \sin \phi}{\cos V \cos \theta - \sin V \sin \theta \cos \phi},$$

$$\tan \psi' = \frac{\sin V \sin \phi}{\cos V \cos \theta + \sin V \sin \theta \cos \phi}.$$

Taking for the extinction-angle (ϵ) the angle which the internal bisector of IPI' makes with PC, we have—[2]

$$2\epsilon = \psi - \psi'.$$

There are two cases to be distinguished, according as θ is less or greater than $\frac{\pi}{2} - V$. We take the former and more important case first.

[1] Compare "Extinction-Angles in Cleavage-Flakes." By Alfred Harker. Min. Mag. 1893, Vol. X, p. 239.

[2] The extinction-angle is here reckoned from the projection of the vertical axis. In practice it would be measured from the trace of some pinacoid or prism-plane, but for a small degree of obliquity the difference is negligible.

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If then θ is less than $\frac{\pi}{2}-V$, and therefore CP greater than CI, $\epsilon=0$ both for $\phi=0$ and for $\phi=\frac{\pi}{2}$, and reaches a maximum for some intermediate value of ϕ, θ being supposed given. From the above relations we obtain without difficulty

$$\tan^2\phi(\sin^2V+\cos^2V\cos^2\theta)-2\tan\phi\sin^2V\sin\theta\cot2\epsilon+(\cos^2\theta-\sin^2V)=0,$$

an equation giving two values of ϕ between 0 and $\frac{\pi}{2}$ for a given value of ϵ less than the maximum. To find this maximum we make the two values of ϕ equal. The condition for this is

$$(\sin^2V\sin\theta\cot2\epsilon)^2=(\sin^2V+\cos^2V\cos^2\theta)(\cos^2\theta-\sin^2V),$$

which reduces to

$$\sin 2\epsilon=\frac{\sin V\tan V}{\cos\theta\cot\theta}.$$

The accompanying table is calculated from this simple relation. It gives the highest extinction-angles that can occur in sections of different degrees of obliquity. It is to be observed that $2V$ is here the angle between the optic axes measured over C, *i.e.* so that the vertical axis bisects it. The table shows that sections with a small obliquity will not give any considerable departure from straight extinction, except when $2V$ is a wide angle. Indeed it is a rough general rule that the maximum extinction-angle is less or greater than the obliquity of the section, according as $2V$ is less or greater than 180°.

It would be easy, if desired, to find the chance that a random section of given obliquity would have an extinction-angle higher than a given value (ϵ); for this chance is evidently the ratio of $\phi_1-\phi_2$ to $\frac{\pi}{2}$, where $\tan\phi_1$ and $\tan\phi_2$ are the roots of the equation given above, and it can be shown that

$$\tan(\phi_1-\phi_2)=\frac{2\sqrt{(\sin^4V\sin^2\theta\operatorname{cosec}^2 2\epsilon-\cos^2V\cos^4\theta)}}{(1+\cos^2V)\cos^2\theta}.$$

Finally, if θ is greater than $\frac{\pi}{2}-V$, and therefore CP less than CI, it is easy to see that there is no limit to the extinction-angle. As ϕ changes from 0 to $\frac{\pi}{2}$, ϵ changes from $\frac{\pi}{2}$ to 0, passing through all intermediate values.

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Values of $2V$.	Values of θ.								
	1°	2°	3°	4°	5°	10°	15°	20°	30°
20°	0°	0°	0°	0°	0°	0¼°	0¼°	0¼°	0½°
30	0	0	0	0¼	0¼	0½	0¾	1	1½
40	0	0¼	0¼	0¼	0¼	0¾	1	1⅓	2⅓
50	0	0¼	0¼	0¼	0½	1	1½	2¼	3⅓
60	0¼	0¼	0½	0½	0¾	1½	2¼	3¼	5½
70	0¼	0½	0½	0¾	1	2	3¼	4⅔	7⅔
80	0¼	0½	0¾	1	1¼	2¾	4¼	6	10½
90	0¼	0¾	1	1½	1¾	3½	5¼	8	14
100	0½	1	1¼	1¾	2¼	4¾	7¼	10¼	18¾
110	0½	1¼	1¾	2¼	3	6	9½	13½	25¾
120	0¾	1½	2¼	3	3¾	7¾	12¼	17¾	—
130	1	2	3	4	5	10¼	16½	24½	—
140	1¼	2½	4	5¼	6½	16	22¾	—	—
150	1¾	3½	5⅓	7¼	9¼	20	—	—	—
160	2¾	5¾	8½	11½	14¾	—	—	—	—
170	5½	11¾	18¼	26½	—	—	—	—	—

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A simple proof of the rationality of the anharmonic ratio of four faces of a zone.

By Harold Hilton, B.A.,

Fellow of Magdalen College, Oxford.

(Communicated by Prof. H. A. Miers.)

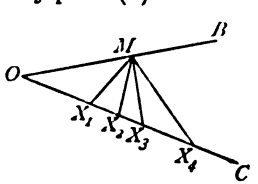
[Read November 13th, 1900.]

THE anharmonic ratio here considered is that of the pencil (P) formed by the four lines (lying in a plane perpendicular to the zonal axis) drawn from any point M perpendicular to four faces of the zone. The anharmonic ratio of the pencil P is evidently independent of the position of M.

Let four planes be drawn through M perpendicular to the four lines of the pencil P; these are parallel to the crystal faces and meet in a line (the line through M perpendicular to the plane of the pencil P and parallel to the zonal axis).

These four planes are cut by the plane of the pencil in a pencil having the same angles, and therefore the same anharmonic ratio, as the pencil P. Now it is a well-known theorem that the pencil in which four planes through a line are cut by *any* plane, has a constant anharmonic ratio; hence the anharmonic ratio of the pencil P is equal to the anharmonic ratio of the pencil in which the four planes through M parallel to the crystal faces are cut by any plane (π).

Let OA, OB, OC, be the positions of the crystallographic axes, and a, b, c their lengths. We noticed above that the anharmonic ratio of the pencil P is independent of the position of its vertex M; we may take M therefore on the axis OB, and take the plane of OB, OC as the plane (π).



Let $h_1k_1l_1$, $h_2k_2l_2$, $h_3k_3l_3$, $h_4k_4l_4$ be the indices of the four faces; then their intercepts on the axes are

$$\frac{a}{h_1}, \quad \frac{b}{k_1}, \quad \frac{c}{l_1}, \quad \&c.$$

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Let OC cut the four planes through M parallel to the crystal faces in X_1, X_2, X_3, X_4. Then we have proved that the pencil P has the same anharmonic ratio as the pencil $M\ (X_1X_2X_3X_4)$; *i.e.* as the range $(X_1X_2X_3X_4)$.

Therefore the anharmonic ratio of the pencil P

$$= \frac{(OX_3 - OX_1)\ (OX_4 - OX_2)}{(OX_4 - OX_1)\ (OX_3 - OX_2)}.$$

Now, $\dfrac{OX_1}{OM} = \dfrac{\frac{c}{l_1}}{\frac{b}{k_1}} = \dfrac{ck_1}{bl_1}$, &c.

or $OX_1 = OM\,\dfrac{ck_1}{bl_1}$; $OX_2 = OM\,\dfrac{ck_2}{bl_2}$; $OX_3 = OM\,\dfrac{ck_3}{bl_3}$; $OX_4 = OM\,\dfrac{ck_4}{bl_4}$

and therefore the ratio of the pencil P

$$= \frac{\left(\frac{ck_3}{bl_3} - \frac{ck_1}{bl_1}\right)\left(\frac{ck_4}{bl_4} - \frac{ck_2}{bl_2}\right)}{\left(\frac{ck_4}{bl_4} - \frac{ck_1}{bl_1}\right)\left(\frac{ck_3}{bl_3} - \frac{ck_2}{bl_2}\right)} = \frac{(l_1k_3 - l_3k_1)\ (l_2k_4 - l_4k_2)}{(l_1k_4 - l_4k_1)\ (l_2k_3 - l_3k_2)}.$$

which is rational, for l_1, l_2, l_3, l_4 and k_1, k_2, k_3, k_4 are rational.

Exactly similarly it may be proved that the ratio P

$$= \frac{(k_1h_3 - k_3h_1)\ (k_2h_4 - k_4h_2)}{(k_1h_4 - k_4h_1)\ (k_2h_3 - k_3h_2)} = \frac{(h_1l_3 - h_3l_1)\ (h_2l_4 - h_4l_2)}{(h_1l_4 - h_4l_1)\ (h_2l_3 - h_3l_2)}.$$

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Addition to a former note[1] *on the rotation of points and planes about an axis.*

By R. W. H. T. Hudson, B.A.,

Fellow of St. John's College, Cambridge.

(Communicated by Prof. W. J. Lewis, M.A.)

[Read January 22nd, 1901.]

THE evaluation of the determinant

$$\Delta_1 = \begin{vmatrix} l_1 & m_1 & n_1 \\ \cos\lambda & \cos\mu & \cos\nu \\ x & y & z \\ \overline{OP} & OP & \overline{OP} \end{vmatrix}$$

occurring at the foot of page 345, Vol. XII, can be effected without first squaring it. Multiply Δ_1 by

$$(1+2\cos\alpha\cos\beta\cos\gamma-\cos^2\alpha-\cos^2\beta-\cos^2\gamma)^{\frac{1}{2}},$$

say $D^{\frac{1}{2}}$, which is the value of the determinant

$$\begin{vmatrix} l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \\ l_3 & m_3 & n_3 \end{vmatrix}.$$

The result is

$$\Delta_1 D^{\frac{1}{2}} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ \cos\theta_1 & \cos\theta_2 & \cos\theta_3 \end{vmatrix}.$$

Similarly Δ_2 and Δ_3 may be evaluated.

Further D_1 (p. 347) is the value of $\rho^{-1}\Delta_1$ after $\rho h/a$, $\rho k/b$, $\rho l/c$ have been substituted for $\cos\theta_1$, $\cos\theta_2$, $\cos\theta_3$ respectively. Accordingly[2]

$$D_1 D^{\frac{1}{2}} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ h/a & k/b & l/c \end{vmatrix}.$$

[1] Min. Mag. 1900, Vol. XII, p. 343.

[2] This result is due to Mr. T. J. I'A. Bromwich, M.A., Fellow of St. John's College, Cambridge.

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Thus the final formulæ (7) are :

$$\frac{h'}{a}-\frac{h}{a}\cos\phi=$$

$$\sin\phi\, D^{-\frac{1}{2}}\begin{vmatrix} 1 & \cos\omega_1 & h/a \\ \cos\gamma & \cos\omega_2 & k/b \\ \cos\beta & \cos\omega_3 & l/c \end{vmatrix}-\cos\omega_1(1-\cos\phi)\,D^{-1}\begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a \\ \cos\gamma & 1 & \cos\alpha & k/b \\ \cos\beta & \cos\alpha & 1 & l/c \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0 \end{vmatrix};$$

with similar expressions for k'/b and l'/c.

The formulæ of transformation for the case in which the angle of rotation is 180° can be found as follows :—

Since the point N is the middle point of PP', its projection on each axis is midway between the projections of P and P' on the same axis :—

$$\therefore\ OP\cos\theta_i+OP'\cos\theta_i'=2\,ON\cos\omega_i;$$

$$\therefore\qquad \cos\theta_i+\cos\theta_i'=2\cos\omega_i\cos PON.$$

Let as before the plane

$$hx/a+ky/b+lz/c=1$$

become $h'x/a+k'y/b+l'z/c=1$.

Then we must put $\cos\theta_1=\rho h/a$, &c. ; $\cos\theta_1'=\rho h'/a$, &c.

Hence $$\frac{h+h'}{a\cos\omega_1}=\frac{k+k'}{b\cos\omega_2}=\frac{l+l'}{c\cos\omega_3}=2\frac{\cos PON}{\rho};$$

where $\dfrac{\cos PON}{\rho}$ is given by equation (8) of page 347, Vol. XII.

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Note on a British Occurrence of Mirabilite.

By C. O. Trechmann, Ph.D., F.G.S.

[Read January 22nd, 1901.]

IN August, 1900, several specimens of this mineral were found attached to gypsum-rock supplied to me from the quarry at Kirkby Thore, in Westmoreland, by Messrs. Joseph Robinson & Co., Ld., of Carlisle, who kindly inform me that the bed of this rock is about 20 feet thick, being overlaid by about 22 feet of marl, &c. There is very little anhydrite, not more than 2 or 3 inches, which, as a rule, is found in the middle of the bed of gypsum. Although I have used this rock for commercial purposes for years past in regular quantities, yet the mirabilite was never previously noticed.

The best specimen consisted of a layer, of about $\frac{1}{8}$ inch in thickness and about 2 inches long and broad, of perfectly clear, pellucid and colourless mirabilite, attached to the parent rock, a moderately coarse grained, dark grey gypsum; the specimen probably represented a portion of a lenticular cavity, originally completely occupied by the mirabilite, as the surface of the rock where the mirabilite rested exhibited minute clear crystals of gypsum. The mirabilite was of irregular form, having been partially dissolved here and there, and the exposed surface was more or less changed, by loss of water, to a white powder. On fracturing the salt, however, it was found, as already stated, to be perfectly limpid and colourless, with marked conchoidal fracture, and exhibiting on some of the fragments a perfect cleavage in one direction.

The following results were obtained, on analysis of clear unaltered fragments, by my assistant, Mr. G. P. Best. The water was estimated by careful heating up to 110°C in a platinum crucible, the residual salt dissolved in water acidulated with hydrochloric acid and the sulphuric anhydride precipitated as barium sulphate; the filtrate was treated with ammonium carbonate and the barium thus removed, and finally the sodium determined as chloride. Other constituents could not be detected.

				Percentage composition.	Calculated for $Na_2SO_4+10H_2O$.
Salt taken for analysis ..	·8800 gram.				
H_2O found ..	·4865 = ·4865	„	H_2O	= 55·28	55·90
$BaSO_4$ „ ..	·6450 = ·2657	„	SO_4	= 30·19	29·81
NaCl „ ..	·3100 = ·1219	„	Na	= 13·85	14·29
	·8741	„		99·32	100·00

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The mirabilite is therefore a very pure Glauber Salt. Crystal faces were not observed, a fact easily understood when the great solubility and liability to efflorescence of this salt, and the peculiar natural conditions necessary for its preservation, are considered; and which would lead to the supposition that crystalline gypsum-rock is singularly impervious to percolating waters.

The only previous mention of mirabilite as a British mineral appears to be by D. C. Glen and John Young, Junr.[1] in a "List of Minerals and Rock Specimens found in the Central, Southern, and Western Districts of Scotland"; but the only information they give is "Mirabilite. Hurlet."

[1] Catalogue of Western Scottish Fossils. By J. Armstrong and others (Brit. Assoc. Adv. Sci.), Glasgow, 1876, p. 160.

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Preliminary Note on an Improved Form of Three-Circle Goniometer.

By G. F. Herbert Smith, M.A.,

Assistant in the Mineral Department of the British Museum.

[Read November 13th, 1900.]

IN a previous paper[1] the author pointed out the advantages of a three-circle form of goniometer in the determination of the morphological characters of crystals; the crystal is adjusted once for all, and measurements may be made in any desired zone. A description was added of such an instrument, which had resulted from the addition of a two-circle apparatus to an ordinary Fuess goniometer with a single horizontal circle. This instrument has been in almost daily use since the end of June, 1899, and the author is, therefore, in a position to appreciate the ease and celerity with which crystals, however small, may be in this manner measured. As was remarked in the paper quoted above,[2] the adapted instrument has the disadvantage that measurements can only be made through little more than a right angle from the pole in which the zone to be measured and the zone of reference intersect, and, therefore, only half a zone can be measured without readjustment of the circles B and C.[3] To complete the zone, it is necessary to rotate C through a half-turn and to turn B till the axis of C makes the same angle with the vertical as before, but on the other side of it. If the crystal is morphologically perfect and the faces at the intersections of the two zones are present and give good reflections, the necessity for readjustment causes merely a little inconvenience; but, since crystals are seldom so complete and the particular faces may not be present, it will not be possible to obtain by direct measurement the angle between two faces which do not make angles of less than a right angle with the same pole of intersection of the zones,

[1] This Magazine, 1899, XII, 175-182; a translation appeared in Zeits. Kryst. Min. 1900, XXXII, 209-216.

[2] Ibid. footnote on p. 179.

[3] The same notation is employed here as before: A is the horizontal circle whose axis is fixed in space, B the vertical circle whose axis lies in a horizontal plane, and C the third circle.

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and further it will not be possible in general to determine by observation whether three faces lie in the same zone.

The author has now devised a way of overcoming this difficulty by means of a change in the optical arrangements. Since the crystal is supported from underneath, we require the possibility of measuring through 180° from a pole in the zone of reference over the upper half of the crystal to the diametrically opposite pole; in other words, we must be able to obtain reflections from both the faces parallel to *B* without rotating *C*. To effect this, the telescope and collimator are combined into an autocollimating telescope,[1] the tube of which is bent through a right angle in the horizontal plane, so that on rotation round the axis of *A* the circle *B* and the crystal lie on opposite sides of the object glass, and thus a reflection can be obtained from the face nearest the circle *B*, as well as from the parallel face. The author hopes in a future paper to describe in detail an actual instrument of this kind.

[1] If preferred, the telescope and collimator may have separate tubes, but both must lie in a *vertical* plane and be turned through a right angle.

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Sulpharsenites of Lead from the Binnenthal.[1]

Part II.—*Rathite.*

By R. H. Solly, M.A.

(With Plate III.)

[Read November 13th, 1900.]

Rathite, $3PbS.2As_2S_3$.

Literature.

Baumhauer, 1896, Zeits. Kryst. Min. XXVI, 593-602. Crystallography, with Analysis by Bömer. (Abstract Min. Mag. XI, 225.)

Jackson, 1900, Min. Mag. XII, 287. Analyses.

Crystallography.

System: Rhombic. $a : b : c = 0{\cdot}4782 : 1 : 0{\cdot}5112$.

These ratios are calculated from $010 : 350 = 51°27'$ and $010 : 111 = 70°45'$ measured on crystal No. 1 (see p. 81). A new orientation has been chosen for the crystals, so that the well-developed prism zone is vertical, and the cleavage plane, (001) of Baumhauer, becomes (010) to correspond with the cleavage of jordanite. The parametral plane has also been changed, chiefly on account of the pyramid planes. The corresponding forms being:—

Baumhauer	100	010	001	403	095	20.27.0	20.27.15
Solly	100	001	010	110	011	101	111

The axial ratios $a : b : c = 0{\cdot}668099 : 1 : 1{\cdot}057891$, as given by Baumhauer, become on recalculation $a : b : c = 0{\cdot}4787 : 1 : 0{\cdot}5251$.

The crystallographic observations have been made on 25 crystals, obtained from the Lengenbach quarries, in the Binnenthal. The table on page 78 contains a list of 62 known forms, 37 of which have not been observed before.

The base (001) is very rare, and only present as a very narrow plane. The brachypinacoid (010) is always present. The macropinacoid (100)

[1] Part I, General Description and Chemical Analyses, with a Crystallographic Account of Jordanite. Min. Mag. 1900, XII, 282-297.

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is rare, though sometimes fairly well developed. The crystals are always elongated along the Z axis. In the prism-zone (320), (340), (120) and (380) are characteristically well developed planes. The brachydome (011) is often largely developed and finely striated parallel to the X axis. The macrodome (101) is sometimes largely developed and deeply furrowed parallel to its intersection with (111). The pyramid planes, though numerous on some crystals, are always small and brilliant.

LIST OF KNOWN FORMS.

Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.	Symbol.	Indices.	Baumhauer's Indices.
a	100	..	$\frac{5}{2}r$	250	..	$\frac{5}{3}k$	083	..
b	010	001	$\frac{7}{3}r$	370	..	$\frac{7}{3}k$	073	045
c	001	..	$\frac{4}{1}r$	490	7.0.12	$\frac{8}{3}k$	095	..
h	101	..	$\frac{2}{1}r$	120	203	†$\frac{7}{4}k$	074	..
$\frac{8}{3}r$	3.80.9	..	$\frac{7}{4}r$	470	..	$\frac{5}{3}k$	053	0.11.10
18*r*	1.18.0	..	$\frac{5}{3}r$	350	405	$\frac{4}{3}k$	043	..
11*r*	1.11.0	..	$\frac{3}{2}r$	340	101	*k*	011	..
10*r*	1.10.0	..	*r*	110	403	$\frac{10}{11}k$	0.10.11	021
9*r*	190	107	$\frac{8}{7}s$	870	302	$\frac{5}{8}k$	056	..
8*r*	180	106	$\frac{3}{2}s$	320	201	$\frac{1}{3}k$	013	0.16.3
$\frac{22}{3}r$	3.22.0	2.0.11	2*s*	210	..	$\frac{11}{3}q$	3.11.3	..
7*r*	170	..	3*s*	310	401	3*q*	131	..
$\frac{20}{3}r$	3.20.0	105	4*s*	410	..	$\frac{5}{2}q$	252	..
6*r*	160	209	$\frac{8}{3}s$	920	601	$\frac{7}{3}q$	373	..
$\frac{17}{3}r$	3.17.0	8.0.35	7*s*	710	..	$\frac{5}{3}q$	353	..
$\frac{16}{3}r$	3.16.0	..	8*s*	810	..	*p*	111	..
$\frac{14}{3}r$	3.14.0	207	†15*k*	0.15.1	..	3*t*	313	..
4*r*	140	103	7*k*	071	..	5*t*	515	
$\frac{11}{3}r$	3.11.0	23.0.66	5*k*	051		2*p*	211	..
$\frac{10}{3}r$	3.10.0	205	$\frac{7}{4}k$	072	.	2*m*	122	..
3*r*	130	..	3*k*	031	..	$\frac{3}{2}w$	132	..
$\frac{8}{3}r$	380	102						

† Twin planes, not found as faces.

The colour is lead-grey, but sometimes steel-grey, due probably to the inclusion of minute crystals of iron pyrites. Sometimes beautifully tarnished like jordanite. Streak chocolate colour. Opaque. Very perfect cleavage parallel to (010)[1]; also a parting parallel to (100). Fracture conchoidal. Hardness 3. Specific gravity 5·412, also 5·421: Baumhauer found 5·82. It is sometimes intimately associated with sartorite. The only known locality is the bed of the Lengenbach, Binnenthal.

[1] See Min. Mag. Vol. XII, 286.

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Five different *habits* have been observed :—

I. Small, very brilliant lead-grey crystals, highly modified, showing little or no twinning. Fig. 1, Plate III.

II. Stout crystals of typical rhombic habit; (010) (011) (101) and prism faces are largely developed. Colour lead-grey to steel-grey. The most characteristic features of this habit are the numerous twin lamellæ and the parting parallel to (100). Analysed by Jackson (*loc. cit.* No. 13). This habit resembles Baumhauer's crystals, I and VI? Figs. 2 and 8.

TABLE OF CALCULATED ANGLES.

Zone [010, 100].		010, 870 = 67°17½′		Zone [010, 101].	
010, 3.80.0 =	4°29′	, 320 =	72 19	010, 3.11.3 =	37°59½′
, 1.18.0 =	6 37½	, 210 =	76 33	, 131 =	43 40
, 1.11.0 =	10 46	, 310 =	80 56½	, 252 =	48 53
, 1.10.0 =	11 49	, 410 =	83 11	, 373 =	50 49½
, 190 =	13 5	, 920 =	83 56	, 353 =	59 48
, 180 =	14 39	, 710 =	86 5½	, 111 =	70 45
, 3.22.0 =	15 55	, 810 =	86 35	, 313 =	83 21½
, 170 =	16 38	, 100 =	90 0	, 515 =	86 0
, 3.20.0 =	17 25	Zone [010 : 001].		, 101 =	90 0
, 160 =	19 13	010, 0.15.1 =	7 26	Zone [010, 102].	
, 3.17.0 =	20 15½	, 071 =	15 37	010, 132 =	55 56
, 3.16.0 =	21 24½	, 051 =	21 22	, 122 =	65 44
, 3.14.0 =	24 8½	, 072 =	29 12	Zone [100, 011].	
, 140 =	27 36	, 031 =	33 6½	100, 211 =	27 43
, 3.11.0 =	29 42	, 083 =	36 16	, 111 =	46 25
, 3.10.0 =	32 6	, 073 =	39 59	, 122 =	64 33
, 130 =	34 52½	, 095 =	47 23	, 011 =	90 0
, 380 =	38 6½	, 074 =	48 11	..	..
, 250 =	39 54½	, 053 =	49 34	010, 211 =	77 47
, 370 =	41 52	, 043 =	56 20½	100, 101 =	43 5½
, 490 =	42 54	, 011 =	62 55½	001, 211 =	65 32
, 120 =	46 16½	, 0.10.11 =	65 4½	, 111 =	49 50
, 470 =	50 4½	, 056 =	66 55½	, 353 =	53 48½
, 350 =	51 27	, 013 =	80 20	, 122 =	36 29
, 340 =	57 29	, 001 =	90 0	, 373 =	58 1½
, 110 =	64 26½			, 252 =	59 1½
				, 132 =	43 4
				, 131 =	61 51
				, 3.11.3 =	65 8

III. Flat rhombic prisms, with narrow (010) and well developed brachydomes. Exhibiting twin lamellæ, but not so numerous or so well marked as in habit II. Analysed by Jackson (No. 11). Fig. 4.

IV. Large rough crystals with splendid (010) cleavage; *no twin lamellæ*; of a dark steel-grey colour; usually mistaken for dufrenoysite. Similar to crystals II and III of Baumhauer. Analysed by Jackson (No. 12).

V. Rounded prisms roughly terminated, with very numerous fine twin

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lamellæ ; of a lead-grey colour sometimes beautifully tarnished. Similar to crystal IV of Baumhauer. Fig. 5.

Twin laws.

I. Twin plane (074).

This twinning is only indicated by numerous very fine twin lamellæ.

II. Twin plane (0.15.1).

This is rare as a juxtaposed twin (Fig. 3), but fairly common as shown by small blade shaped prisms grown on the prism of the principal crystal. Two twinned crystals, as shown in Fig. 2 and in Baumhauer's Fig. 2, have been observed forming a triplet. The planes (074) (0.15.1) are not developed on any of the crystals.

Baumhauer, in his description of rathite, discusses the following possible causes of the fine striæ.

(*a*) Are the layers due only to parallel growth ?

(*b*) Are the layers due to twin growth ?

(*c*) Are the layers due to alternate banding of two isomorphous substances ?

On account of the analysis obtained by Bömer, Baumhauer considered that the fine striæ are due to alternate banding of $PbAsS_3$ and $PbSbS_3$ in the proportion of five molecules of the former to one of the latter. Jackson, out of five analyses of different rathite crystals, only once found any antimony (0·48 per cent.), while Bömer made one analysis and found 4.53 per cent. of antimony. I think there can be no doubt that the true composition of rathite is expressed by the formula $8PbS.2As_2S_3$, and therefore the chemical composition has nothing to do with the fine striæ.

Are the layers then parallel growths or twin growths? Parallel layers would require some impurity between each layer, but Jackson did not find any difference in the chemical composition between crystals showing the lamellar structure and those not showing it. Parallel layers, as a rule, are uneven in thickness, and pass through the whole crystal. Now, these layers are remarkable for their even thickness, and do not always spread through the whole crystal or exhibit a pseudo-cleavage parallel to the layers. In the juxtaposed twin, described on page 83, one crystal shows lamellar structure, while in the other it is absent.

I therefore consider that the fine striæ are caused by twin lamellæ parallel to (074).

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Baumhauer points out the close crystallographic relation between rathite and dufrenoysite. I shall in my concluding paper on this group discuss the morphotropic relationship of the whole group.

There is a specimen of rathite labelled "arsenomelane" in the Museum of Practical Geology, London. The name "arsenomelane" was given by von Waltershausen, and he supplied material for the analyses of Uhrlaub and Nason: the results[1] of these analyses agree closely with the formula $3PbS.2As_2S_3$, and there can be little doubt that most of the "arsenomelane" found in 1855-7 was rathite.

Description of Specimens.

Habit I. Fig. 1, Plate III.

This habit was observed on eight small crystals. One very small crystal, Fig. 1, was especially good.

Thirty-seven forms were determined, viz.:—

a, *b*, $\frac{8}{3}^0r$, 18*r*, 11*r*, 9*r*, $\frac{22}{3}r$, 6*r*, $\frac{14}{3}r$, 4*r*, $\frac{10}{3}^0r$, 3*r*, $\frac{8}{3}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, 2*r*, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, *r*, $\frac{3}{2}s$, 2*s*, 3*s*, 4*s*, 7*s*, $\frac{7}{3}k$, $\frac{5}{3}k$, *k*, $\frac{11}{3}q$, 8*q*, $\frac{5}{2}q$, $\frac{7}{3}q$, $\frac{5}{3}q$, *p*, 2*p*, 2*m*, $\frac{3}{2}w$.

	Calculated.		Measured.	
010, 3.80.0 =	4°29′	...	4°27′ to 4°31′	narrow plane
, 1.18.0 =	6 37½	...	6 35 to 6 40	,,
, 1.11.0 =	10 46	...	10 44 to 10 47	,,
, 190 =	13 5	...	13 2 to 13 5	,,
, 3.22.0 =	15 55	...	15 52 to 15 56	,,
, 160 =	19 13	...	19 11 to 19 14	,,
, 3.14.0 =	24 8½	...	24 6 to 24 8	,,
, 140 =	27 36	...	27 32 to 27 38	,,
, 3.10.0 =	32 6	..	32 3 to 32 9	,,
, 130 =	34 52½	...	34 52 to 34 53	,,
, 380 =	38 6½	...	38 6 and 38 7	fairly large plane
, 370 =	41 52	...	41 50 to 41 52	narrow plane
, 490 =	42 54	...	42 51 to 42 57	,,
, 120 =	46 16½	...	46 16 and 46 18	large plane
, 470 =	50 4½	...	50 2 to 50 7	narrow plane
, 350 =	51 27	...	51 27	fairly large plane
, 340 =	57 29	...	57 30 and 57 32	large plane
, 110 =	64 26½	...	64 23 to 64 28	narrow plane
, 320 =	72 19	..	72 19	very large plane
, 210 =	76 33	...	76 25 to 76 40	narrow plane
, 310 =	80 56½	...	80 54 to 80 58	,,

[1] Min. Mag. XII, pp. 283 and 287, Nos. 17-20.

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	Calculated.		Measured.	
010, 410	=83 11	...	83 8 to 83 14	narrow plane
, 710	=86 5½	...	86 to 86 10	,,
, 100	=90 0	...	90	small plane
010, 073	=39 59	...	39 53	narrow plane
, 053	=49 24	...	49 30	,,
, 011	=62 55½	...	62 57	small plane
010, 3.11.3	=37 59½	...	37 58 to 38	
, 131	=43 40	...	43 38 to 43 40	
, 353	=59 48	...	59 48 to 59 50	
, 111	=70 45	...	70 44 to 70 46	
100, 111	=46 25	...	46 24 to 46 26	
, 122	=64 33	...	64 30 to 64 36	
, 011	=90 0	...	89 58 to 90 1	
320, 111	=40 48	...	40 47	
, 353	=41 3	...	41 2	
340, 111	=40 39½	...	40 41	
, 353	=36 37	...	36 38	
350, 111	=41 52½	...	41 53	
, 353	=36 11½	...	36 13	
120, 111	=43 26½	...	43 30	
, 353	=36 30	...	36 32	

The forms 211, 132, 373, 252, 131, 3.11.3, 122 were determined by the following zones:—

211 [100, 111] [131, $\bar{1}$20]. 131 [010, 111] [320, $\bar{3}$53].
132 [131, 001] [010, 122]. 3.11.3 [010, 111] [340, $\bar{1}$11].
373 [010, 111] [320, $\bar{1}$11]. 122 [100, 111] [340, 353].
252 [010, 111] [130, 122].

There are also other minute pyramid planes which give no distinct reflections.

Habit II. Figs. 2 and 3.

This habit was observed on nine crystals; (010) (011) and (101) are largely developed, (010) is bright and smooth, (011) dull and finely striated parallel to the X axis, (101) with small (111) (313) (515) are rounded and deeply furrowed parallel to their mutual intersections, (320) (340) and (380) are largely developed.

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Thirty-one forms were determined, viz. :—

a, *b*, *c*, $\frac{8}{3}r$, $9r$, $\frac{22}{3}r$, $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, $4r$, $\frac{10}{3}r$, $\frac{8}{3}r$, $2r$, $\frac{5}{3}r$, $\frac{4}{3}r$, $\frac{3}{2}s$, $3s$, $\frac{9}{2}s$, $7s$, $8s$, $7k$, $5k$, $\frac{7}{2}k$, $3k$, $\frac{8}{3}k$, $\frac{7}{3}k$, k, p, $3t$, $5t$, h.

	Calculated.		Measured.	
010, 3.16.0	$=21°24\frac{1}{2}'$	...	$21°22'$ to $21°25'$	narrow plane
, 920	$=83\ 56$	...	83 52 to 83 58	,,
, 810	$=86\ 35$	...	86 30 to 86 40	,,
, 071	$=15\ 37$	...	15 34 to 15 40	,,
, 051	$=21\ 22$	...	21 20 to 21 26	,,
, 072	$=29\ 12$	...	29 14	,,
, 031	$=33\ 6\frac{1}{2}$	...	33 3 to 33 10	,,
, 083	$=36\ 16$	...	36 12 to 36 18	,,
, 313	$=83\ 21\frac{1}{2}$	...	83 to 83 30	rounded plane
, 515	$=86\ 0$	...	85 to 86	,,
, 101	$=90\ 0$	...	90 about	

The crystals belonging to this habit are always characterised by numerous twin lamellæ, according to law I (twin plane (074)).

Calculated.		Measured.
$010,074 = 48°11'$	...	$47\frac{1}{2}°$ to $48\frac{1}{2}°$

This angle was determined under a microscope fitted with cross wires and graduated circle. The crystals break parallel to (100), on which surface the lamellæ are well seen.

Very often small blade-shaped prisms are grown in twinned position on the prism planes of the principal crystal, according to law II (twin plane (0.15.1)). Triplets were also observed, according to law II (Fig. 2).

	Calculated.		Measured.
$(010), (\overline{010}) = Z\bar{Z} = 14°52'$		...	$15°$
$(\overline{010}), (\overline{\overline{010}}) = \bar{Z}\bar{\bar{Z}} = 29\ 44$		...	30

The above angles were determined under a microscope by means of cross wires and a graduated circle.

One twinned crystal (Fig. 3) requires special notice It is a juxtaposed twin, according to law II, and exhibits on the fractured surface of one crystal numerous twin lamellæ, according to law I.

The prisms are both well developed with (340) very large. On one crystal (072) gives a good reflection, (083) poor, and (073) rounded. The zone [010, 101] is rounded and deeply furrowed.

Calculated.		Measured.
$010, \overline{010} = 14°52'$	...	$14°55'$
$, 072 = 29\ 12$	...	29 14
$010, \overline{010} = 14\ 52$	...	14 50

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This crystal consists of a number of similar crystals not quite parallel, as is seen when measuring round the prism zone.

Habit III. Fig. 4.

This habit was observed on three crystals. (010) is a narrow plane, while (320), (340), (120) and (380) are well developed. The brachydomes are well developed, and give good reflections. The twin lamellæ are not nearly so numerous as in habit II, and the parting plane (100) is *absent*.

Forty forms were observed, viz. :—

a, *h*, *h*, $\frac{8}{3}r$, 18*r*, 11*r*, 10*r*, 8*r*, $\frac{22}{3}r$, 7*r*, $\frac{20}{3}r$, 6*r*, $\frac{17}{3}r$, $\frac{16}{3}r$, $\frac{14}{3}r$, 4*r*, $\frac{11}{3}r$, $\frac{10}{3}r$, 3*r*, $\frac{8}{3}r$, $\frac{5}{2}r$, $\frac{7}{3}r$, $\frac{9}{4}r$, 2*r*, $\frac{7}{4}r$, $\frac{5}{3}r$, $\frac{4}{3}r$, *r*, $\frac{3}{2}s$, 2*s*, 4*s*, 7*s*, 7*k*, 3*k*, $\frac{7}{3}k$, $\frac{9}{5}k$, $\frac{5}{3}k$, $\frac{4}{3}k$, *k*, $\frac{5}{6}k$.

	Calculated.		Measured.		
010, 1.10.0	= 11°49′	...	11°45′ to 11°50′		narrow plane
, 180	= 14 39	...	14 35 to 14 45		,,
, 170	= 16 38	...	16 35 to 16 45		,,
, 3.20.0	= 17 25	...	17 20 to 17 40		,,
, 3.17.0	= 20 15½	...	20 10 to 20 20		,,
, 3.11.0	= 29 42	...	29 40 to 29 45		,,
, 250	= 39 54½	...	39 50 to 40		,,
320, $\bar{3}20$	= 35 22	...	35 22		sharp image
, 340	= 14 50	...	14 50		,,
340, 350	= 6 2	..	6 2		,,
350, 120	= 5 10¼	..	5 10		,,
010, 071	= 15 37	...	15 36		good image
, 031	= 33 6½	...	33 6		,,
, 073	= 39 59	...	39 58		,,
, 095	= 47 23	...	47 20 to 47 25		poor image
, 053	= 49 34	..	49 35		good image
, 043	= 56 20½	...	56 25		poor image
, 011	= 62 55½	...	62 55		fair image
, 056	= 66 55½	...	67		poor image

Habit IV.

This habit was observed on some large rough crystals given to me by Dr F. Grünling, of Munich. They resemble in form habit II, but exhibit no twin lamellæ. These crystals are of a dark steel-grey colour with splendid cleavage parallel to (010). On breaking up the crystals for analysis minute crystals were found lining some of the cavities. Some of

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the planes in the prism and brachydome zones were bright and large enough to measure.

Seventeen forms were observed, viz. :—

b, $18r$, $\frac{2}{3}^2r$, $\frac{1}{3}^6r$, $\frac{1}{3}^1r$, $8r$, $\frac{5}{3}r$, $2r$, $\frac{5}{8}r$, $\frac{3}{2}s$, $2s$, $8s$, $5k$, $\frac{7}{2}k$, $8k$, $\frac{8}{11}k$, $\frac{7}{4}k$.

Habit V. Fig. 5.

This habit was observed on one crystal. The crystal is in a cavity in the dolomite. It is a rounded prism with no definite terminations, with well-marked numerous twin lamellæ on the prism faces ; only approximate measurements could be obtained, but they conform with twin law I. It is identical in appearance to crystal IV of Baumhauer. An untarnished prism of jordanite may easily be mistaken for a rathite of this habit.

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Tinguaites from Elfdalen and Rupbachthal: Basalts from Madagascar and the Soudan.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read June 19th, 1900.]

(I). *Cancrinite-Ægirine-Tinguaite* ("*Sussexite*"), *from Elfdalen, Sweden.*

(II). *Riebeckite-Ægirine-Tinguaite, from the Rupbachthal, Nassau. Compared with similar rocks from Abyssinia and the Canary Islands.*

(III). *Melilite-Basalt from Amparafaravola, Madagascar.*

(IV). *Hornblende-Basalt and Limburgite, from Ahmed Aga, White Nile.*

I. *Cancrinite-Ægirine-Tinguaite* ("*Sussexite*"), *from Elfdalen, Sweden.*

In connection with the investigation of ægirine-anorthoclase rocks from Abyssinia, belonging to the grorudite-tinguaite series,[1] an examination was made of specimens of the so-called green phonolite from Elfdalen, which in the British Museum collection accompanied the more ordinary brown and red porphyry from that locality. In the descriptions of the well-known porphyry quarries of Elfdalen, mention is made of this green variety as occurring only in boulders.[2] Törnebohm was the first to record the occurrence of these rocks *in situ*, and to describe their characters.[3] They were found in the form of dykes in the neighbourhood of Heden, near Särna, Dalarne, Sweden, and were interesting as containing cancrinite in clear, well-defined porphyritic crystals as undoubtedly a primary constituent.

The name *Cancrinite-Ægirine-Syenite* proposed by Törnebohm is a rather misleading one, since neither in structure nor in mode of occurrence can these rocks be rightly regarded as belonging to the syenite group.

[1] Min. Mag. 1900, XII, 255-73.

[2] Hjelm. K. Vetensk. Akad. Nya Handl. 1805, pp. 106-8.

[3] Geol. För. Förh. 1883, VI, 383, and Abst. in Neues Jahrb. f. Min. &c. 1883, (ii),—370-.

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The object of the present note is therefore to point out what appears to be the true position of these rocks in rock-classification as members of the *Grorudite-Tinguaite* series of Brögger.

Most of the rocks are tinguaites, but some are examples from the basic end of the series to which Brögger would apply the name of "*Sussexite*."[1]

Specimens of these more basic varieties in the Museum collection are olive-green felsitic-looking rocks, showing to the naked eye small transparent prismatic phenocrysts of cancrinite, and numerous long black needles of ægirine.

Under the microscope, porphyritic crystals of cancrinite, rounded nepheline and prismatic ægirine are seen in a fine-grained groundmass, consisting of minute felspar needles and a dense mesh of ægirine needles, such as is characteristic of most grorudites. No felspar phenocrysts are present.

The long, deep grass-green phenocrysts in one specimen consist of true ægirine giving nearly straight extinction and compensating with the quartz-wedge along the length. In another specimen, however, somewhat paler green phenocrysts appear to be intermediate between ægirine and ægirine-augite, for the extinction in most sections varies from 10° to 18°, and compensation takes place along the length (a axis of indicatrix 18° from crystallographic axis *c*): some of the sections had darker green ragged terminations of true ægirine, giving nearly straight extinction.

A quantitative analysis of this rock gave the following result (I), as compared with that of nepheline-porphyry ("Sussexite") (II), from Beemerville, New Jersey, described by Kemp[2]:—

		I.		II.
SiO_2	...	48·83	...	45·18
Al_2O_3	...	18·71	...	23·31
Fe_2O_3	...	4·16	...	6·11
FeO	...	1·91	...	
CaO	...	5·19	...	4·62
MgO	...	1·02	...	1·45
Na_2O	...	10·63[3]	...	11·17
K_2O	...	3·04	...	5·95
Ign.(CO_2+H_2O)		5·52	...	1·14
		99·01		98·93

[1] Brögger. Eruptivgesteine des Kristianiagebietes, 1894, I, 173.

[2] Trans. New York Acad. Sci. 1892, XI, 60.

[3] Probably slightly under estimated.

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In mineral composition and structure the rock is obviously closely related to members of the grorudite-tinguaite series, while the analysis shows that in chemical composition it approaches the basic end of the series, the type-rock of which is the so-called nepheline-porphyry of Kemp ("Sussexite" of Brögger) from Beemerville, New Jersey.

The chemical relationship of the Elfdalen rock to other members of the series is seen in the following table[1]:—

	Grorudite Varingskollen.	Grorudite Kallerud.	Sölvsbergite Longenthal.	Tinguaite Hedrum.	Sussexite Elfdalen.	Sussexite Beemerville.
SiO_2	74·35	71·36	62·70	56·58	48·83	45·18
Al_2O_3	8·73	12·21	16·40	19·89	18·71	23·31
$Fe_2O_3(FeO)$	7·21	6·76	5·99	4·34	6·07	6·11
CaO	0·45	0·22	0·95	1·10	5·19	4·62
MgO	0·07	—	0·79	0·13	1·02	1·45
Na_2O	4·51	6·51	7·13	10·72	10·63	11·17
K_2O	3·96	3·22	5·25	5·43	3·04	5·95
$H_2O(CO_2)$	0·25	0·33	0·70	1·77	5·52	1·14

II. *Riebeckite-Ægirine-Tinguaite, from the Rupbachthal, Nassau. Compared with similar rocks from Abyssinia and the Canary Islands.*

This rock has been described as a proterobase[2], and as a diorite-porphyrite.[3] In the present note it is referred to the tinguaite (phonolite) group, owing to the striking resemblance in characters which it presents with tinguaites from Abyssinia, described in the paper already referred to.[4]

Specimens of the rock in the British Museum collection are dark greenish black, and show only a few small phenocrysts of felspar. Under the microscope one or two long phenocrysts of orthoclase (or possibly anorthoclase), with straight extinction and showing no twin striations, are seen in a trachytic groundmass of felspar laths, scattered through which are ragged tufts and feathery patches of grass-green ægirine and riebeckite (with pleochroism from yellow to deep indigo-blue). The latter minerals are especially accumulated round patches of an altered mineral,

[1] See Brögger. Eruptivgesteine des Kristianiagebietes, 1894, I, 176.

[2] W. Schauf, Unters. nassauische Diabase. Inaug.-Diss. Bonn, 1880, p. 17.

[3] Zeits. Deutsch. geol. Ges. 1883, XXXV, 216.

[4] Min. Mag. 1900, XII, 268.

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showing in one or two cases sharp hexagonal outlines. This structure is so very similar to that of the tinguaite from Amba Gollo, near Axum, Abyssinia (see Min. Mag. XII, Pl. III, fig. 5), that the altered mineral is here referred to nepheline. Besides ægirine and riebeckite there are moss-like patches of a nearly opaque mineral which in some parts show pleochroism from pale reddish brown to deep red nearly opaque. The same mineral occurs in small amount in the tinguaite from Abyssinia referred to above, and also in the paisanite described in the same paper. It is most probably the soda-amphibole *Cossyrite*.

Very similar to the Rupbach rock both macroscopically and microscopically are specimens in the Museum collection from Gran Canaria and Teneriffe.

Thus a dark greenish rock from the Guimar Road, Gran Canaria, shows in thin section under the microscope one or two long Carlsbad twins of orthoclase (or possibly anorthoclase, which is the prevailing felspar in many specimens of phonolite from the Canary Islands) in a trachytic groundmass of felspar laths with feathery tufts of ægirine and a hornblendic mineral, showing extinctions as high as 30° and pleochroism from pale yellow to purplish brown, and thus closely related to the *Catophorite* of Brögger: ragged patches of altered *Cossyrite* are also present. A specimen from Tiraxana, Gran Canaria, is similar, and shows also large irregular phenocrysts of altered nepheline surrounded by ægirine, as in the Rupbach rock.

Many of the phonolitic rocks of Cripple Creek, Colorado, described by Cross,[1] appear to be of a very similar character.

III. *Melilite-Basalt from Amparafaravola, Madagascar.*

The specimen of this rock in the Museum collection is from a collection of Madagascar rocks, presented in 1889 by the Rev. J. Wills.

It is a dark, fine-grained basalt, showing in section characters very similar to those of the well-known melilite-basalt of Hochbohl, Württemberg. Very numerous small phenocrysts of olivine occur in a base of pale purple augites, with small prismatic melilites and magnetite grains.

The melilite has a slightly brownish tint, but is clear and free from inclusions like the Hochbohl mineral: it occurs in lath-shaped crystals, often club-shaped at the ends, which give straight extinction and compensate with the quartz-wedge across their length like the Hochbohl melilite: the double refraction is very low to almost isotropic: no peg-structure was observed.

[1] XVI Ann. Rep. U. S. Geol. Survey, 1894-5, Part II, p. 35.

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Purplish-brown, strongly refractive grains are doubtless to be referred to perofskite, the constant companion of melilite.

IV. *Limburgite and Hornblende-Basalt-Scoria from Ahmed Aga, White Nile.*

Ahmed Aga is an isolated hill in the desert country, about 100 miles north of Fashoda, on the White Nile. The specimens here described, which were collected and presented in 1900 to the Museum by Capt. Stanley Flower, show that the hill is of volcanic origin. They consist of basalt-scoria, compact limburgite and large fragments (up to 1 in. square) of basaltic hornblende.

The limburgite or magma-basalt is a dense black rock, showing a few small phenocrysts of olivine. Under the microscope small irregular and rounded phenocrysts of olivine, and a few phenocrysts of a pale purple augite, with colourless centres, are seen in a dense groundmass, made up mainly of pale purple augite microlites, with some olivine and magnetite grains, in a nearly colourless isotropic base. One or two foreign fragments of quartz are present, surrounded by the usual alteration-zone of pale-green augite needles. Many of the olivine phenocrysts have suffered partial absorption, and are surrounded by a broad margin of granular augite.

The basalt-scoria shows in thin section irregular phenocrysts of a pale-green augite, altered olivine, and deep red basaltic hornblende, with one or two small fragments of felspar (showing no twin-striations) in a dense, nearly opaque, glassy base.

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OBITUARIES.

CHARLES FRIEDEL, although most distinguished as a chemist, had a considerable reputation as a Mineralogist and Crystallographer. He was born at Strassburg on March 12th, 1832, and graduated in mathematics and physics at the University of Paris with special honours. His first public appointment (1856) was that of Curator of the Mineralogical Collection of the Paris School of Mines. In 1876 he became Professor of Mineralogy in the University, and eight years later succeeded Professor Wurtz in the Chair of Organic Chemistry. He received the distinguished honour of membership of the Institute (Academy of Sciences) in 1878, and in 1881 was President of the French Mineralogical Society. His numerous mineralogical papers deal with the pyroelectrical phenomena of crystals, the artificial production of minerals, and other subjects of a miscellaneous and descriptive character. The minerals adamite, wurtzite, delafossite and (in conjunction with another author) carnotite were first described by him; the mineral friedelite perpetuates his name.

Friedel's death took place on April 20th, 1899. A detailed account of his mineralogical work, together with an excellent portrait, is given by P. Curie in *Bull. Soc. franç. Min.* 1900, XXIII, 171-190.

PETER WAAGE, an original honorary member of the Society, died in January 1900, in his 67th year. Since 1862 he had held the post of Professor of Chemistry in the University of Christiania. As a chemist he was interested in the analysis of minerals, and he was also joint author of a primer of crystallography.

TOWNSHEND MONCKTON HALL, an original member of the Society, and a contributor to the Magazine, died July 1st, 1899, at the age of 54. He was well known as a local authority on the geology and mineralogy of Devonshire, and was the author of a very useful topographical index to British mineralogy, "The Mineralogist's Directory," published in 1868.

REVIEWS.

Elements of Mineralogy, Crystallography and Blowpipe Analysis from a practical standpoint. By A. J. Moses, Professor of Mineralogy, Columbia University, and C. L. Parsons, Professor of General and Analytical

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Chemistry, New Hampshire College. New enlarged Edition. Pp. vii+414. 664 Figures. (New York: D. Van Nostrand Company, 1900. Price $2.00 net.)

This is one of the best text-books that can be recommended to students of elementary mineralogy. Clear and concise statements in short paragraphs are admirably arranged under prominent head-lines, so that the text is easy to read and convenient for reference. On many pages there are eight different kinds of type. The book is full of excellent illustrations of an original character; those from photographs of actual specimens are, as a rule, good, but others, as might be expected, do not show very much, and would have been better omitted.

Part I, dealing with crystallography, describes the more important of the 32 classes of crystals; there are also short chapters on the measurement and drawing of crystals, but no mention is made of stereographic projection. Part II gives an excellent account of the methods of blow-pipe analysis. The third part, headed descriptive mineralogy, includes five chapters on the optical and other characters of minerals, and these might very well have formed a part by themselves. The chapters on optical characters will be useful to beginners in microscopic petrography.

This edition differs considerably from the first edition of 1895; there are 328 more figures, the crystallography and determination tables have been re-written, and the remainder extensively revised.

A Text-book of Important Minerals and Rocks, with Tables for the Determination of Minerals. By S. E. Tillman, Professor of Chemistry, Mineralogy and Geology, U.S. Military Academy, West Point, N.Y. Pp. viii+176. 38 Figures. (New York: John Wiley & Sons. London: Chapman & Hall, 1900. Price $2.00 net.)

This book is quite elementary, and, in fact, almost popular in character. The most unsatisfactory part is that dealing with crystallography, which is very sketchy and contains many incorrect statements, while head-lines like the following only lead to confusion:—"*Crystallographic Law—Law of Axial Ratios, or Rationality of Parmeters* [*sic*] *or Indices.*" The part giving descriptions of 75 common minerals is better, but here the arrangement of the main headings requires considerable revision: for example, native copper and cinnabar come, without any break in the text, under ores of silver. Tables for the determination of the 75 species are unduly long, occupying no less than 40 pages. The concluding part gives a short account of rocks on the lines adopted in elementary text-books of geology.

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ABSTRACTS.

Minerals of Ceylon. A recent number of Groth's *Zeitschrift* (Band XXXIII, Heft 3-5, 1900) contains a series of important papers resulting from Dr. F. Grünling's mineralogical expedition to Ceylon in 1896-7. Dr. Grünling himself gives a general account (pp. 209-239) of the geology and mineralogy of the island, and of the industries connected with pearl fishing, graphite mining, and the washing of gem-gravels. An excellent map gives the positions of the mineral localities: these are almost all situated in the south-central portion of the island. The crystalline rocks (granulites) contain veins of graphite, and beds of limestone and dolomite, in which are various crystallised minerals. The precious stones, the principal localities for which are Ratnapura and Rakwana, are extracted from the gravels of existing and of ancient streams; they include sapphire, less frequently ruby, chrysoberyl, spinel (often of a fine blue colour), zircon, tourmaline, rutile, garnet, several varieties of quartz, &c. The corundum and spinel appear to have been derived from the crystalline limestones.

This paper includes a description, with several analyses, by E. C. Schiffer (also in Inaugural-Dissertation, München, 1900, pp. 32-45) of a coarsely crystalline dolomite, from Wattegama, near Kandy, and of the minerals enclosed in it, namely, blue apatite, phlogopite, hydrophlogopite, serpentine, pyrites, pyrrhotite, and spinel.

A paper (pp. 263-454), by V. von Worobieff, gives a detailed crystallographic description of the tourmaline crystals collected by Dr. Grünling (supplemented by other material); this is illustrated by seven plates, with 99 figures. With few exceptions these crystals are brown in colour, and vary in habit from lenticular to prismatic; they are brilliant and very rich in forms, there being as many as 59 on one crystal. A long list of crystal forms includes no less than 131 which have not been observed before, and a table of measured and calculated angles extends over 43 pages. The rhombohedral angle rr' is determined as 47°13′39″ (mean of 48 angles on 15 crystals, with the limits 47°5½′ to 47°19′); this corresponds with $a : c = 1 : 0{\cdot}45181$. No definite connection could be traced between the development of the faces and the pyroelectrical character of the two ends of the crystals, and there are many exceptions to Rose's rule as quoted in the text-books. The antilogous pole, how-

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ever, shows many unusual forms, and the faces are further distinguished by striations and irregularities of growth; except in the case of crystals showing complex combinations, the two poles can only be distinguished by a pyroelectrical examination. The symmetry of tourmaline, as shown by the development of the faces and the etch-figures, is ditrigonal-pyramidal (acleistous-ditrigonal class of Lewis), and not hemimorphic-tetartohedral (acleistous-trigonal of Lewis) as has been suggested by a few authors.

G. Melczer (pp. 240-262) gives crystallographic and optical determinations of the chrysoberyl, sillimanite and blue spinel. Sillimanite is represented by a single prismatic crystal, which is transparent and pale-blue, with peculiar pleochroism.

The same number of the *Zeitschrift* also contains a description by V. Goldschmidt and H. Preiswerk (pp. 455-467) of a twin-crystal of chrysoberyl, brought from Ceylon by Prof. C. Schmidt. From their own and from Melczer's measurements these authors deduce the most probable values of the axial ratios of chrysoberyl as $a : b : c = 0{\cdot}4708 : 1 : 0{\cdot}5823$.

Mention may here be made of a recent paper "On Ceylon Rocks and Graphite," by A. K. Coomára-Swámy (*Quart. Journ. Geol. Soc.* 1900, LVI, 590-615). This is mainly a description of the crystalline rocks and the mode of occurrence of graphite. Chemical analyses are given of some rock-forming minerals; and minerals from the gem-gravels are briefly described, with a list of observed crystalline forms in the case of corundum. L. J. S.

Minerals from South Greenland. (G. Flink, O.B.Boeggild and C. Winther, *Meddelelser om Grönland*, 1900, XXIV, 1-213, 9 Plates).—This long paper, which is written in English, describes in detail the large amount of material collected by Dr. Flink in the summer of 1897 in the nepheline-syenite district of Julianehaab. The first part (pp. 7-180) by Flink deals with 34 mineral species collected from a coarse gravel, which has resulted by the weathering *in situ* of pegmatite masses in the syenite, on the plateau of Narsarsuk. Nine new species were determined, namely, ancylite, chalcolamprite, cordylite, endeiolite, leucosphenite, lorenzenite, narsarsukite, spodiophyllite, tainiolite, and a new variety of apatite—yttrium-apatite. A summary of the characters of these has already been given in this Magazine (vol. XII, p. 378). Among other crystallised minerals may be mentioned ægirite, arfvedsonite, catapleiite, elpidite, epididymite, eudidymite, eudialyte, neptunite and parisite.

The second part (pp. 181-213), by Boeggild and Winther, gives the characters of the new minerals epistolite, britholite and schizolite (see Min. Mag. XII, p. 378), and also of steenstrupite. L. J. S.

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Chemical Composition of Sulphohalite. (S. L. Penfield, *Amer. J. Sci.* 1900, [iv], IX, 425-428, and *Zeits. Kryst. Min.* 1900, XXXIII, 523).—From the single partial analysis which has previously been made of sulphohalite the formula was deduced as $3Na_2SO_4.2NaCl$. Recent attempts by de Schulten and by van't Hoff and Saunders to prepare this compound artificially have failed, and the existence of sulphohalite has consequently been doubted. A new analysis of the mineral was therefore desirable. This was performed on a portion of the original crystallised material, and the results give the new formula $2Na_2SO_4.NaCl.NaF$. The presence of fluorine is unexpected, but may be explained by the borax deposits of Borax Lake, San Bernardino Co., California, having been formed by fumarole action. Intimately associated with sulphohalite is hanksite ($9Na_2SO_4.2Na_2CO_3.KCl$), a mineral also containing three acid radicles. L. J. S.

Chemical Composition of Turquoise. (S. L. Penfield, *Amer. J. Sci.* 1900, [iv], X, 346-350, and *Zeits. Kryst. Min.* 1900, XXXIII, 542).—The formula of turquoise is usually given as $2Al_2O_3.P_2O_5.5H_2O$, the copper, which is always present, being considered to be an accidental impurity to which the colour of the mineral is due. In order to establish a formula a new analysis has been made on carefully selected material from the Crescent Mining district, Lincoln Co., Nevada. This is of a fine robin's-egg blue colour, and breaks with a smooth fracture; under the microscope it appears to be homogeneous, and there is no evidence of the presence of two substances. The results of the analysis are :—

P_2O_5.	Al_2O_3.	Fe_2O_3	CuO.	H_2O.	Insol.	Total.	Sp. gr.
34·18	35·03	1·44	8·57	19·38	0·93	99·53	2·791

A consideration of this and other reliable analyses suggests that the copper is present as an essential constituent of the mineral, and this is also supported by the fact that finely-powdered turquoise dissolves in hydrochloric acid as a whole without discolouration. The new formula, $[Al(OH)_2,Fe(OH)_2,Cu(OH),H]_3PO_4$, represents the mineral as a derivative of ortho-phosphoric acid, with the hydrogen atoms largely replaced by the univalent radicles $Al(OH)_2$, &c. In some analyses approximately two-thirds of the hydrogen atoms are so replaced, and the formula becomes $[Al(OH)_2, Fe(OH)_2, Cu(OH)]_2HPO_4$. L. J. S.

Chemical Composition of Tourmaline. Two more papers have recently been contributed to the discussion now taking place concerning the composition of tourmaline. (See Abstract, *Min. Mag.* XII, 216, 309.)

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S. L. Penfield replies (*Amer. J. Sci.* 1900, X, 19-32; and *Zeits. Kryst. Min.* 1900, XXXIII, 527) to the various criticisms of his formula, and makes some interesting general remarks as to the reliability of mineral analyses.

E. A. Wülfing (*Programm z. 82 Jahresfeier d. k. Württemb. landwirt. Akad. Hohenheim*, 1900, 99 pp.) discusses the connection between the crystallographic constants and the chemical composition, and represents in a coloured diagram the results of the 33 best tourmaline analyses. Previously published constants are discussed, and numerous new crystallographic, optical and density determinations are given of material which was, whenever possible, the same as that analysed by previous authors. For crystals from various localities the angle rr' varies from 46°48′ to 47°15′, the corresponding values of the c axis being 0·4469 and 0·4521 respectively. The refractive indices and double refraction also vary considerably: $\varepsilon = 1{\cdot}6159$ to $1{\cdot}6572$; $\omega = 1{\cdot}6354$ to $1{\cdot}6918$ (for line E). Sp. gr. 3·007 to 3·240. The double refraction and the sp. gr. both increase with the amount of iron. Four groups of tourmaline may be distinguished, namely, those rich in (1) lithium, (2) ferrous iron, (3) ferric iron, and (4) magnesium. The iron tourmalines are black, but those of the second group have pale reddish-violet and blue as axial pleochroism colours, while those of the third group have brownish and dark-green.

New analyses of tourmaline are given by H. Beermann (*Inaug.-Diss. Erlangen*, 1899; Abstract in *Neues Jahrb. Min.* 1900, II, Ref. 26).

L. J. S.

Dianumd Field of the Great Lakes. (W. H. Hobbs, *Journal of Geology*, 1899, VII, 375-388.)—Since 1883 seventeen diamonds, varying in weight from ¼ to 21¼ carats, have been found in glacial deposits in the region of the great lakes of North America, principally in the State of Wisconsin. The predominating crystal forms are the rhombic dodecahedron and a hexakis-octahedron; the stones are colourless or tinted with green or yellow. By plotting the diamond localities and directions of the glacial striæ on a map it is seen that the diamonds probably came from somewhere near James Bay on Hudson Bay, though a more detailed study of the glacial geology of the region will be needed before the home of the diamond can be exactly located. L. J. S.

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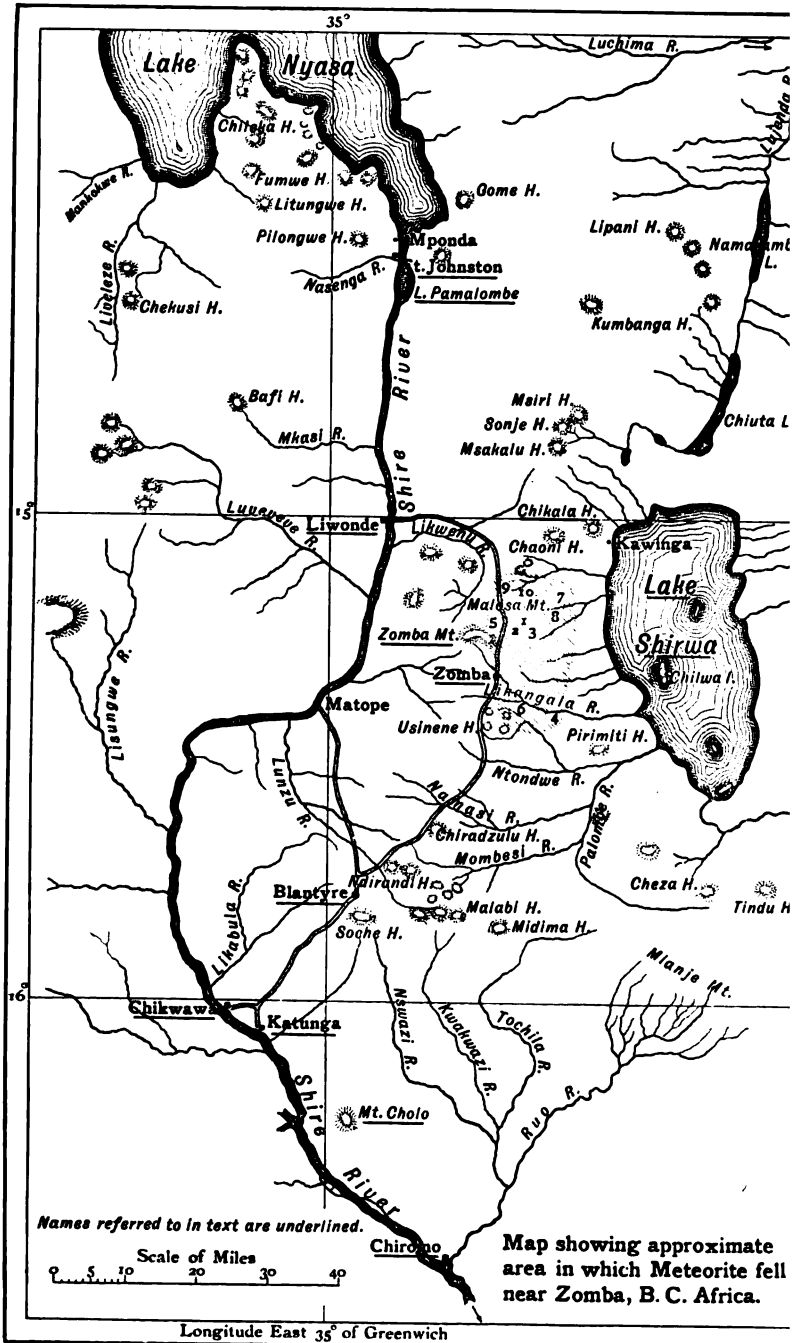

L. FLETCHER: ZOMBA METEORITE.

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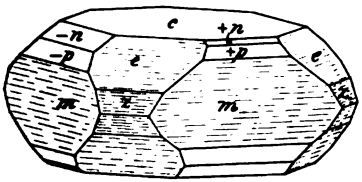
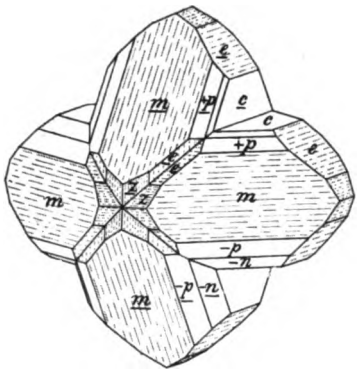


Fig. 1.



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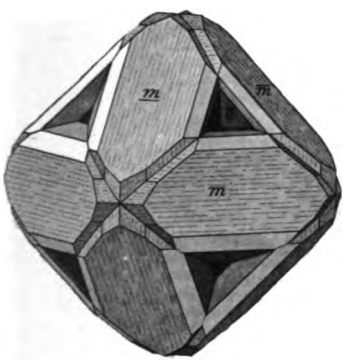
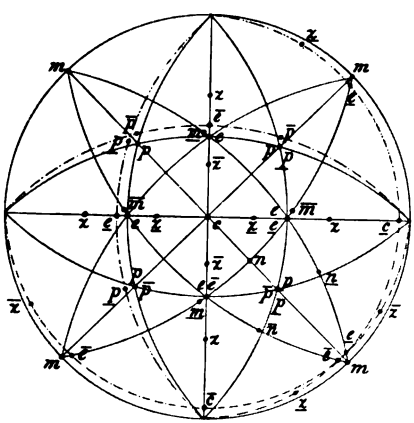


Fig. 3.

Fig. 4.



L. J. S. *del.*

Fig. 5.

L. J. SPENCER: STANNITE FROM BOLIVIA.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

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No. 60. MAY, 1902. Vol. XIII.

COMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY.

On an Occurrence of Minerals at Haddam Neck, Connecticut, U.S.A.

By H. L. BOWMAN, M.A.

Demonstrator in Mineralogy.

(With Plate IV.)

[Read March 19, 1901.]

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IN the summer of 1896 the Oxford Museum was enriched by a fine series of about eighty mineral specimens from a newly opened quarry at Haddam Neck in Connecticut, which were kindly presented by Mr. Ernest Schernikow of New York.

The species included in the series are green and pink tourmaline, albite, microcline, green and pink apatite, brown fluor, beryl, quartz,

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cookeite, lilac lepidolite, greenish-white muscovite, and a peculiar pink fibrous variety of the same mineral. To these must also be added, as occurring at the same place, green fluor, microlite, and columbite.

The locality is described as Haddam Neck, a village opposite to Haddam, on the other (eastern) bank of the Connecticut River, which is here about half a mile wide.

Mr. Schernikow gives the following account of the occurrence:—'The deposit is what I would call a vein of very coarse granite—that is, the quartz, felspar, and mica are in very large pieces. Quartz and felspar predominate, mica being also quite abundant, and sometimes in plates 2 ft. across. The tourmalines and associated minerals, like lepidolite, beryl, cookeite, etc., occur usually in pockets, all of which are lined with crystallized quartz and felspar, and sometimes beryl. *All* the minerals occur in these pockets. The deposit is well defined between walls of country rock—possibly gneiss, but I am not positive.'

In the following description of the species, the position of the crystals and the lettering of the faces are throughout those used in Dana's 'System of Mineralogy' (1892); as are also the axes, except in the case of tourmaline, where the faces are referred to the rhombohedral axes of Miller. In the case of apatite and beryl, the letters and indices used by Miller (in his edition of Phillips's 'Mineralogy') are added.

THE MICAS.

Intergrowth of Muscovite and Lepidolite.

Perhaps the most interesting minerals of the occurrence are the micas. Stout hexagonal or rhombic prisms terminated at right angles by the basal plane are found associated with smoky quartz, albite, microcline, cookeite, and sometimes tourmaline. They have ordinarily a diameter of 1·5 to 3 or 4 cm., but to judge from one tabular (cleavage) specimen, they appear to attain a diameter of 8 cm. They are usually terminated by cleavages, but some specimens attain a length of 4 cm. When broken across, they are found to consist either of transparent lilac lepidolite throughout, or (more usually) of an outer zone of this mineral surrounding an inner nucleus of yellowish- or greenish-white muscovite, the cleavage being parallel in both border and centre.

Pink Fibrous Muscovite.

The outer surface of the prisms has a fibrous appearance due to a thin layer of longitudinal fibres of a pink mineral, and at the ends the lepidolite is covered (in unbroken specimens) by a layer of the

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same material, often 1 cm. or more in thickness, the fibres being always parallel to the axis of the prism. The fibrous mineral has a perfect cleavage perpendicular to its fibres, and thin plates can be split off from it parallel to the cleavage of the lepidolite nucleus. Such plates form beautiful objects under the microscope, when they are seen to be built up of minute rhombic units, with angles of 60° and 120°, fitted together in three positions, forming tesselated areas which extinguish in three positions, 120° apart—each rhomb extinguishing parallel to its diagonals (fig. 1, plate IV). In convergent light the rhombs show a nearly normally-emergent negative bisectrix of rather wide angle, the plane of the optic axes lying along the longer diagonal.

These characters indicated a mineral belonging to the group of micas, and an analysis became necessary in order to determine the species.

The material analysed was of a uniform light rose-pink, and quite clean and free from any brown crust. Its specific gravity (before crushing) was 2·791.

A small amount of water is given off on heating the dried powder in the closed tube, and a qualitative examination showed the presence of SiO_2, Al_2O_3, Fe_2O_3 (or FeO), MnO, K_2O, Na_2O, Li_2O, F, P_2O_5. The MnO is sufficient to give the fused carbonates a pale bluish-green tinge, and is probably the cause of the pink colour of the mineral, but it does not appear to be present in weighable amount.

The finely powdered mineral was found to show practically no loss of weight after being exposed for forty-eight hours over calcium chloride, and a very trifling loss after being heated for two hours to about 96° in a water-oven. For the quantitative determinations, therefore, the material was dried in this manner.

The water was estimated by Penfield's direct method[1], the mineral, mixed with previously well dried litharge to retain fluorine, being heated by a Bunsen burner in a closed hard-glass tube with a bulb on its neck kept cool by wet filter-paper. The neck containing the water was cut off and weighed, the water then tested and found neutral, and the neck dried and again weighed. Further heating of the residual material in the blowpipe produced no more water. In two experiments, 0·0975 and 0·0759 grams of the dried mineral gave 0·0043 and 0·0033 grams of water, corresponding to 4·41 and 4·35 per cent. respectively of water [mean 4·38 per cent.].

The fluorine was determined according to the method of Berzelius; two experiments with 0·1186 and 0·2531 grams of the dried mineral

[1] Amer. Journ. Sci., 1894, ser. 3, vol. xlviii, p. 31.

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yielding (after removal of one-tenth of the solution to test for P_2O_5) 0·0008 and 0·0018 grams of calcium fluoride, corresponding to a total percentage of fluorine of 0·37 and 0·385 [mean 0·377].

The determinations of the silica by the Berzelian method were not concordant, and this constituent was therefore estimated in the usual way by evaporation of the carbonate-fusion with acid, the amount of fluorine being so small that any loss of silica which it might cause (the maximum possible being just over three-quarters of its weight) must be insignificant. Seven experiments yielded the numbers given below. The acid solution was in each case evaporated twice on the water-bath and extracted through separate filters, and in nos. 3, 4, 5, 6 the residue after the second evaporation was heated to 110° in an air-bath, till it no longer gave off acid fumes. In the case of nos. 3, 4, 7, nitric acid was used instead of hydrochloric acid.

The weighed silica was exposed in the open platinum crucible to the fumes of hydrofluoric acid (produced from a mixture of NH_4HF and strong sulphuric acid) for 12–15 hours in a closed leaden box[1] over a small flame placed some distance below, and the silica determined by the loss of weight.

	1	2	3	4	5	6	7	
Weight of mineral .	0·3827	0·2423	0·3023	0·3208	0·3069	0·3045	0·3004	
Weight of SiO_2 . .	0·1792	0·1112	0·1399	0·1475	0·1419	0·1409	0·1396	
Percentage of SiO_2 .	46·83	45·89	46·28	45·98	46·24	46·27	46·47	mean 46·28

The filtrates from the silica in nos. 1, 2, 6 were precipitated hot with ammonia, the precipitate washed, dissolved in nitric acid, and reprecipitated; the precipitate of Al_2O_3, Fe_2O_3, P_2O_5, after weighing, was tested for manganese by fusion with carbonates, but gave hardly any perceptible green colouration. The weights of the precipitates were 0·1456, 0·0917, 0·1153 grams, corresponding to 38·05, 37·85, 37·87 per cent. of $(Al_2O_3+Fe_2O_3+P_2O_5)$ respectively. [Mean 37·92 per cent.]

The filtrates from the silica in no. 5 and in another experiment with 0·3077 gram of the dried mineral, were precipitated with ammonia, the precipitate washed and redissolved in dilute sulphuric acid, the iron

[1] Such a box may conveniently be made of a piece of 4 in. lead pipe, about 4 in. long, with the ends filed true and closed by flat plates of sheet lead. The crucible is covered with a loose roof of platinum foil to protect the silica from any particles falling from the lid of the box.

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reduced with zinc and titrated with permanganate. The results showed 1·07 and 0·87 per cent. of ferric oxide, respectively. Ferrous iron was not separately determined. [Mean Fe_2O_3=0·97 per cent.]

In the filtrate from no. 7, the phosphoric acid was separated with ammonium molybdate and estimated as $Mg_2P_2O_7$. The result showed the presence of 0·09 per cent. P_2O_5.

Taking the means of the determinations and calculating the alumina by difference gives 36·86 per cent. Al_2O_3.

For the estimation of the alkalies the mineral was decomposed by the Lawrence Smith method and the separation of the lithium effected by means of amyl alcohol as recommended by Gooch[1]. The lithium was weighed as lithium sulphate. The potassium was separated from the sodium in the residue as K_2PtCl_6, the latter ignited, and the resulting platinum washed and weighed. The weight of sodium was obtained by difference.

The results of three experiments with 0·3096, 0·3049, and 0·3986 grams of the dried mineral, after correction for the solubility of the various alkaline salts in the amyl alcohol, gave the following percentages:—

	1	2	3	mean
Li_2O	0·31	0·25	0·21	0·26
K_2O	10·90	10·53	10·46	10·63
Na_2O	1·37	1·52	1·33	1·41

The composition of the mineral may then be taken as:—

	I. Haddam Neck.	Goshen. II. Rbg.	Goshen. III. Mallet.
SiO_2	46·28	47·02	
Al_2O_3	36·86	36·83	
Fe_2O_3	0·97 (incl. FeO)	0·51	
MnO	trace	1·05	
K_2O	10·63	9·80	9·08
Na_2O	1·41	0·30	0·99
Li_2O	0·26		0·64
P_2O_5	0·09	—	
F	0·377	0·52	1·89
H_2O	4·38	3·90	
	101·257	99·93	
less O	0·158		
	101·099		

[1] Proc. Amer. Acad. Arts and Sci., 1886, new ser., vol. xiv, p. 177; Bull. U. S. Geol. Survey, 1887, no. 42, p. 73; Chem. News, 1887, vol. lv, p. 18, et seq.

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The mineral is therefore a variety of muscovite, and may be compared with the pink variety of muscovite from Goshen (Massachusetts), the analysis of which, by Rammelsberg[1], is quoted in column II. A determination of the alkalies of the same by Mallet[2] is also given in column III.

A small fragment of a fibre detached from the side of a specimen admitted of measurement on the goniometer, and proved to be a very steep pyramid (fig. 2, plate IV[3]), the vertical faces not lying in a zone. The angles are:—

	Measured.	Calculated.
SS	$= 59° 52'$	$59° 58'$
$\pi\pi$	$= 59\ 43$	$59\ 52$
cS	$= 88\ 21\frac{1}{2},\ 88° 21'$	$88\ 36\frac{1}{2}$
$c\pi$	$= 86\ 38,\ 86° 33'$	$86\ 28$

The plane of symmetry is thus parallel to the shorter diagonal of the rhomb. The measured angles lead to the indices $S\ \{551\}$ and $\pi\ \{552\}$. Both forms are new for muscovite, but $S\ \{551\}$ is given by Dana for biotite. The corresponding calculated angles given above are based on Tschermak's axes $a : b : c = 0{\cdot}57735\ \ 1 : 3{\cdot}3128$; $\beta = 89° 54'$, as adopted by Dana for muscovite.

The axial angle measured in air is:—

$$2E = 75\tfrac{1}{2}°\ (\text{Na light}).$$

Dispersion, $\rho > v$ (slight).

The acute bisectrix is perhaps not quite normal to the plate, and in some instances seems to deviate a few degrees *in* the plane of the optic axes (i. e. across the plane of symmetry), but owing to the small size of the rhombs and the difficulty of isolating them, the position of the plate-normal has not been ascertained with certainty.

Some of the cleavage flakes show a bright line, which does not extinguish, along the boundary between the areas with different orientation, due to overlapping of the contiguous elements, and corresponding with the obliquity of the prism faces with respect to the cleavage.

The tesselated structure gives the mineral an opaque appearance to the naked eye, though the separate elements are transparent. The size of the small rhombs is on the whole very uniform, being about 0·18 mm. for the longer diagonal, but a few isolated fibres reach 0·65 mm.

I was for a long while unable to find any specimens from other

[1] Min.-Chem., 1875, p. 514.

[2] Amer. Journ. Sci., 1857, ser. 2, vol. xxiii, p. 180.

[3] The convergence of the faces is somewhat exaggerated in the figure.

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localities at all resembling the present mineral, but among the lepidolites in the Vienna Museum I came upon a single large tabular crystal of muscovite bordered by a zone of lilac lepidolite, outside which was a small quantity of rhombic, tesselated material. The specimen is from Auburn, Maine, and proves on examination to be very similar to those of the Haddam Neck occurrence. The rhombs are fitted together in twin-position, extinguishing 120° apart. The axial plane is parallel to the longer diagonal. The axial angle is rather wide ($2E=75°20'$), and the figure shows distinct axial dispersion, $\rho > v$. The lilac lepidolite has its axial plane parallel to one of the rays of the percussion figure, and is therefore brachydiagonal. It is much twinned. The muscovite centre is macrodiagonal, with rather wide axial angle, and very distinct dispersion, $\rho > v$. The whole specimen very closely resembles the large tabular crystal from Haddam Neck mentioned above.

Lepidolite.

The solid prisms of lepidolite and the borders surrounding muscovite form extremely fine examples of this mineral. The material is of a beautiful lilac colour and perfectly transparent. To the eye it appears quite uniform and homogeneous, but application of the percussion test combined with the microscope, shows that the crystals fall really into two groups, in one of which the axial plane is brachydiagonal, while in the other it is macrodiagonal. It may be mentioned that the lepidolite yields a percussion figure much less readily than the muscovite, being more flexible and less elastic than it.

Lepidolite is usually stated to belong to the macrodiagonal group of micas, but brachydiagonal lepidolite has been described by Scharizer[1] from Schüttenhofen in Bohemia, where the zonal growth of the lepidolite and muscovite and the tourmalines appear to show a general resemblance to those of the present occurrence. Cleavage plates of the Haddam Neck lepidolite do not as a rule extinguish at all unless very thin, owing to the superposition of layers of material in twin-position. Thin plates show an irregular patchwork of areas extinguishing 120° apart. The axial angle is variable on account of the twinning, but appears to be generally smaller than that of the muscovite.

Both the brachy- and macrodiagonal varieties show a slight dispersion of the optic axes, in the sense $\rho > v$. The brachydiagonal flakes show a deviation of the bisectrix from the plate-normal in the plane of the optic axes. The macrodiagonal flakes also show a deviation of the

[1] Zeits. Kryst. Min., 1886, vol. xii, p. 1.

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bisectrix of from 5¼°–7½° from the centre of the microscope field, which is again in the plane of the optic axes, and therefore in this case in the plane perpendicular to (010). A deviation of this sort would contradict the assumption of monoclinic symmetry for the crystals, and it was therefore of importance to determine if the effect was real or due to instrumental errors (such as want of perpendicularity between the stage and the axis of the microscope), or to the somewhat uneven cleavage flake not lying flat upon the stage.

A small and exceptionally plane flake having been chosen, it was cemented on to a thin cover-glass in such a position that when mounted on the goniometer the best image of the signal reflected from the mica was not more than a few minutes distant from that reflected from the glass. The parts of the flake yielding other images were covered with a mask of paper. The mounted flake was then placed on a disc of glass laid flat on the stage of the microscope (Dick pattern), and capable of rotating in its own plane within a cardboard ring. The positions of the optic axes O_1O_2 in the field were read off on an eyepiece-micrometer, first in one position (A), and then after rotating the plate on the stage through 180° (B). The mean of O_{1_A} and O_{1_B} (or O_{2_A} and O_{2_B}) gives the reading for the plate-normal, while those of O_{1_A} and O_{2_A} and of O_{1_B} and O_{2_B} give readings for the bisectrix in the two positions.

A flake, which was subsequently proved by percussion to be macrodiagonal, showed a deviation of the bisectrix from the plate-normal of 6½° in the plane of the optic axes, the inclination of the mica to the cover-glass being only 16′. The true deviation of the bisectrix from the normal to the flake in the plane of the optic axes cannot therefore be less than 6¼°.

Hence it must be concluded that, unless a ray of the percussion star is perpendicular to (010) [1], this mica belongs to the anorthic system.

With the nicols in the extinction position, the lateral shift of the axial brush produced by a rotation of the plate through 180° falls within the errors of observation. The axial plane is thus sensibly normal to the plane of cleavage.

Another flake, examined as above, which turned out to be brachydiagonal, showed a deviation of 4¾° in the plane of the optic axes, the

[1] There seems no reason to doubt that the star belongs to a percussion- and not to a pressure-figure, as its form agrees exactly with the type figured by Max Bauer (Zeits. Deutsch. geol. Gesells., 1874, vol. xxvi, pl. II, fig. 2, and copied in Hintze's Mineralogy, vol. ii, p. 518, fig. 236).

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mica being nowhere inclined more than 7′ to the plate on which it was mounted.

Greenish-white Central Muscovite.

The central core of many of the mica crystals consists of greenish- or yellowish-white muscovite, and a similar material also occurs in irregular flakes dispersed in parallel positions through massive quartz.

The centre of the large tabular crystal mentioned above (p. 98) has an axial angle in air[1]:—

$$2E = 75° 38'.$$

That of a smaller rhombic-shaped prism has:—

$$2E = 74° 35'.$$

The material is a perfectly normal muscovite—the axial plane is macrodiagonal, and there is a well-marked axial dispersion, $\rho > v$.

Zonal Growth and Twinning of the Micas.

(1) *Lepidolite on Muscovite.*—The line of junction between the central muscovite and the lepidolite border is occasionally irregular, but more usually straight and sharp. The outline is generally either rhombic or hexagonal, corresponding to faces in the zone [c, (110)] and the clinopinakoid {010} of the muscovite. The obtuse angles of the rhomb are often truncated by small faces of a {100}, and the angles between {010} and {110} are frequently replaced by short edges apparently representing several different forms. The indices of these can scarcely be determined owing to the shortness of the edges and the rounding of the angles, but Q {130} is probably present, and two faces at angles, respectively, of 23° and 24° from {110}, may belong to a form {870}, for which the calculated angle (taking (110) : ($1\bar{1}0$)=60°) is 23° 25′. Seven measurements (varying from 59° to 60½°) of the plane angle of the rhomb on the microscope-stage yielded 59½° as the mean value of that angle.

The relation of the lepidolite border to the central muscovite is somewhat difficult to determine, owing to the twinned structure of the former; the untwinned areas being so small as to admit only exceptionally of the production of a recognizable percussion figure.

Immediately outside the junction is generally (but not always; see fig. 4, pl. IV) a narrow band of lepidolite (L_m) which extinguishes in the same position as the muscovite, the axial planes being also parallel (fig. 3, pl. IV). The percussion star, which I have succeeded in obtaining on

[1] For the muscovite-centre of the zoned mica from Schüttenhofen, the axial angle (as given by Scharizer) is $2E = 70°$–$74°$.

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two specimens, shows this zone to consist of the macrodiagonal variety grown in parallel position on the muscovite.

Outside this inner zone of lepidolite, and occasionally also in direct contact with the muscovite, are irregular patches (L_b) having their axial planes parallel to one side or the other of the rhombic outline of the muscovite, i.e. at 30° in one direction or the other from that of the muscovite. Those of these patches which have yielded me a percussion figure are found to be brachydiagonal, and all are probably to be explained as brachydiagonal mica in twin-position according to the ordinary 'mica-law' (twin plane {110}).

The extinction of the lepidolite and also of the muscovite in the neighbourhood of the junction, is somewhat wavy, and cannot therefore be determined with sufficient accuracy to afford an answer to the questions, whether the lepidolite in contact with muscovite is twinned on that mineral or on the zone of lepidolite parallel to it (in cases like fig. 4), and whether the latter is absolutely parallel with the muscovite or grown upon it with the prism faces in common. The wavy extinction may probably itself be an indication of the strain set up by want of complete coincidence between the molecular structures of the two minerals.

In the larger crystals, the lepidolite border is composed of intimately twinned material and scarcely extinguishes anywhere. Here and there, however, in thin flakes, small patches may be found, on which the extinction directions may be determined. Those adjoining the junction have their axial plane parallel to that of the muscovite and are probably macrodiagonal; others, in the body of the lepidolite, have the axial plane inclined at 30° to that of the muscovite, and are shown by the percussion figure to consist of the brachydiagonal variety in twin-position.

The outer boundary of the lepidolite is consistently parallel to its junction with the muscovite, though in the larger crystals it is somewhat rough and irregular. This parallelism is maintained irrespective of the face which is in contact with the muscovite; thus, along the prism edge of a muscovite rhomb, in the case of lepidolite in either parallel position or twin-position about that prism face, the outer edge corresponds to {110}, while both the line of contact and the outer edge of an area of lepidolite twinned about the other prism face, represent {010} (see fig. 4).

(2) *Pink fibrous Muscovite on Lepidolite.*—The junction of the lepidolite with the border of pink fibrous muscovite is usually quite sharp and straight. The small rhombs are either in parallel position on the lepidolite or twinned upon it according to the ordinary mica-law. The general structure of the border is shown in fig. 5, pl. IV, which represents

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a flake from a hexagonal lepidolite prism without any central core of muscovite. The flake consists of three macrodiagonal lepidolite crystals, irregularly twinned together, and the sides of the hexagon are formed principally by {010}; {110} is also present on one individual, and the corners of the hexagon are truncated by short edges corresponding to {130}.

The arrangement of the rhombs round brachydiagonal lepidolite is quite similar, the crystals being sometimes attached in parallel and sometimes in twin-position, and the axial planes being at 90° and 30° respectively to that of the lepidolite.

The chief points of interest shown by this occurrence of micas may be thus summarized:—

A new variety of muscovite, which appears to be scarcely met with elsewhere, is here very abundant. It consists of masses of pink fibres of rhombic section attached together in parallel or twin-position, so that the whole mass can be cleaved across like a single crystal. The fibres generally occur surrounding, or at the ends of, lepidolite crystals, and at first sight resemble an alteration-product of the latter.

The lilac-coloured lepidolite occurs either in solid prismatic crystals or as a border surrounding greenish-white muscovite, and comprises two varieties, differing only in the position of the optic axial plane, which is parallel respectively to the brachydiagonal or macrodiagonal axis. In the latter case, a deviation of the acute bisectrix from the plane (010) indicates that this mica is to be referred to the anorthic system. The lepidolite is usually much twinned on the ordinary 'mica-law.' The muscovite is generally surrounded by a narrow zone of macrodiagonal lepidolite (fig. 3, pl. IV) in parallel position, while outside this are patches of brachydiagonal lepidolite twinned on each other and on the zone of macrodiagonal material. Among them are sometimes found patches of the macrodiagonal variety. I have found no instance of brachydiagonal lepidolite attached to the muscovite in parallel position, nor of macrodiagonal in twin-position, but brachydiagonal lepidolite is sometimes in direct contact with the muscovite in twin-position (fig. 4, pl. IV).

The lepidolite is often surrounded by a layer of the rhombic fibres of pink muscovite in either parallel or twin-position, the arrangement being similar round both brachy- and macrodiagonal varieties.

The intimate association of the two varieties of lepidolite does not seem to have been observed before, and being thus unsuspected it caused

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at first some little difficulty in explaining the relations of the border to the muscovite.

No case was observed in which any other than the ordinary twin-law need be invoked in order to explain the relative positions of the various areas.

Colourless Muscovite.

Besides the greenish-white muscovite described above in association with the lepidolite, there also occur large sheets (sometimes two feet across, as Mr. Schernikow reports) of ordinary clear colourless muscovite, such as is used commercially, which is brownish in thick sheets. This mica contains thin included films of a dark material appearing bronze-coloured by reflected light, and opaque or of a very dark grey by transmitted light under the microscope. The inclusions are hexagonal in outline, the sides of the hexagons being perpendicular to the percussion-rays, and are traversed by cracks perpendicular to the sides of the hexagons; they reach a breadth of 2–3 mm., but are mostly smaller. I have not been able to isolate, or determine the nature of these inclusions owing to their extreme thinness. They do not appear to affect the magnetic needle.

Flattened tabular and elongated crystals of black, brown, and green tourmaline are also enclosed in this mica. The axial plane of the mica is macrodiagonal and the axial angle in air, $2E = 71° 0'$.

Tourmaline.

The tourmaline occurs in the form of beautiful, transparent, striated prisms, of curved triangular outline or flattened, and varying much in colour—the most usual colours being shades of light and dark green and pink[1]. A few crystals are almost perfectly colourless. Crystals frequently exhibit transverse bands of different colours, which are usually separated from each other by perfectly sharp planes perpendicular to the prism, or the junctions may be slightly hazy though still parallel to (111). In one case, the junction between a pale green and a pink band shows the form of the trigonal pyramid $\{11\bar{1}\}$ (fig. 6), and sometimes the pyramidal termination $\{11\bar{1}\}$ shows a thin parallel layer covering the faces of an earlier termination of the same form but of a different colour. The frequency of the occurrence of the basal plane alone among these colour divisions is somewhat remarkable, as this form is usually but poorly developed in the present terminations of the crystals. Occasionally the later growth has extended from the terminal

[1] Mr. Spencer informs me (January, 1902) that the pink specimens in the British Museum have faded very markedly during four years' exposure in a glass case.

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band backwards along the prism, forming an outer zone of differently coloured material.

The crystals bear no resemblance to the well-known tourmalines 'from Haddam,' which are black.

The crystals are frequently doubly-terminated: they vary in habit from short and stout (30 mm. long and 20 mm. diam.) to long and slender (80 × 4 mm.)[1], and small, almost acicular crystals are found scattered over the surface of larger ones or embedded in other minerals.

The following forms are present:—

Antilogous pole . . o {11$\bar{1}$}
Analogous pole . . e {01$\bar{1}$}, r {$\bar{1}$00}, c {111}.

There does not appear to be any connexion between the colours of the ends and the polarity of the crystals.

G. Rose stated[2] that, as a general rule, that end at which the faces of the principal rhombohedron [trigonal pyramid] (RR=46° 54′) lie over the edges of the trigonal prism, is the antilogous pole, and vice versa, but found that crystals from Penig in Saxony formed an exception to this rule, having the faces of R over the *faces* of the trigonal prism at the antilogous pole.

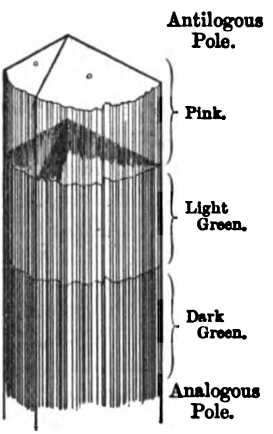

FIG. 6.—Banded crystal of tourmaline showing an internal 'ghost.' (Length 30 mm., diam. 5 mm.)

This rule may be taken as equivalent to the statement that (the antilogous pole being placed uppermost) +R {100} {$\bar{1}$00} and the prism {$\bar{2}$11} are the more commonly occurring forms as compared with the corresponding inverse forms − R {22$\bar{1}$} {$\bar{2}$21} and {2$\bar{1}$1}. An exception to the rule may be due to the presence of either (a) the rarer inverse pyramids −R {22$\bar{1}$} {$\bar{2}$21} (combined with {$\bar{2}$11}), or (b) the rarer complementary trigonal prism {2$\bar{1}$1} (combined with +R). The occasional occurrence of the latter prism on tourmaline is proved by the simultaneous existence, on crystals from Bovey Tracey, Sonnenberg in the Harz, and Gouverneur, of both trigonal prisms, of which {2$\bar{1}$1}

[1] Some specimens in the British Museum attain a length of 5 inches, and Kunz mentions and figures (18th Ann. Rep. U. S. Geol. Survey, 1896-7 (1897), part v, pp. 1183, 1204; 20th Rep., 1898-9 (1899), part vi (2), plate I, fig. E) a perfect crystal 10 in. long × 1 in. diam. in Mr. Bement's Collection.

[2] Ann. Phys. Chem. (Poggendorff), 1836, vol. xxxix, p. 285; 1843, vol. lix, p. 357.

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in the first two cases sometimes, and in the latter case habitually predominates[1].

The exception in the case of the Penig crystals is perhaps to be explained (as Rose at first suggested) on the first assumption, as the R-faces are very rough and the faces of the flatter rhombohedron truncating the edges of R, very smooth and shining, while normally the reverse of this is found to hold. (According to von Worobieff, however, this explanation is not likely to be correct.)

An examination of a number of the Haddam Neck crystals by Kundt's method showed them to conform to the above rule; they also confirm Rose's further statement that the basal plane only occurs on the analogous pole.

The faces of r {100} are always bright, while those of e {011} are usually so, but occasionally dull and drusy; o {11$\bar{1}$} is bright but generally somewhat pitted.

The mean pyramid-angle of {11$\bar{1}$}, as determined from four measurements on pink crystals, is 76° 37′ (76° 18′—76° 45′), giving 114° 4′ for the axial angle. Two measurements on green crystals gave 76° 45′ as the pyramid-angle, corresponding to 114° 0′ as the angle between the axes.

The lighter coloured crystals are usually but slightly pleochroic, while in some of the darker green varieties the ordinary ray is almost completely absorbed. The pleochroism corresponding to the various colours is indicated in the following table:—

Colour.	Vibrations	
	∥ axis (extraordinary ray).	⊥ axis (ordinary ray).
Rose-pink	Dark pink	Ruby.
,, ,,	Pink	Pink.
,, ,,	Very pale lilac	Brown-pink.
Nearly colourless	Pale blue	Pale brown-pink.
Bluish green	Pale blue	Light olive.
,, ,, (darker)	Leek-green	[Nearly dark.]
Greyish green	Greyish green	Olive.
Light green	Pale greenish blue	Olive-green.
Dark green	Grass-green	[Dark.]
Violet	Pale mauve	[Nearly dark.]

[1] V. von Worobieff has recently found in the course of his exhaustive study of tourmaline (Zeits. Kryst. Min., 1900, vol. xxxiii, p. 419) a large number of exceptions to Rose's rule, so that the latter can no longer be said to be of general application. The number of forms on the crystals from Haddam Neck is too small to permit the determination of the polarity by the rules proposed by v. Worobieff, but the occurrence of o {11$\bar{1}$} at the antilogous pole is in accordance with his observations.

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Some of the 'uniform, rather pale green crystals' have been analysed by Penfield and Foote[1], who give the following composition:—

$SiO_2 = 36{\cdot}96$, $TiO_2 = 0{\cdot}03$, $B_2O_3 = 11{\cdot}00$, $Al_2O_3 = 39{\cdot}56$,
$FeO = 2{\cdot}14$, $MnO = 2{\cdot}00$, $MgO = 0{\cdot}15$, $CaO = 1{\cdot}28$,
$Na_2O = 2{\cdot}10$, $Li_2O = 1{\cdot}64$, $H_2O = 3{\cdot}10$, $F = 1{\cdot}13$.

Total =	101·09
less O =	0·48
	100·61

Flattened tabular crystals of black tourmaline are found (as are also thin prisms of the green variety) between the laminae of large sheets of the ordinary white muscovite; but no black crystals appear to occur in association with the other minerals, though a few green crystals are so dark as to appear almost black.

Kunz states[2] that a number of crystals have been found showing marked internal striations, arranged in such a way as to show in gems cut across the crystal a line of light, similar to the 'cat's-eye' variety of chrysoberyl from Ceylon.

Apatite.

Two varieties of this mineral are found, viz. thick hexagonal tables or short prisms (up to 2 cm. diam.) of a pale greyish green, and rose-coloured crystals having the form of short, stout prisms terminated by the basal plane. The prism- and basal-edges of both varieties are modified by narrow faces.

The greenish crystals occur embedded in albite and quartz: the pink crystals in the Oxford Collection do not show any matrix.

The following are the forms found on the pink crystals:—

Bowman.	Dana.		Miller.	
	m	{10$\bar{1}$0} . . .	*a* {10$\bar{1}$}	
	a	{2$\bar{1}$10} . . .	*b* {2$\bar{1}\bar{1}$}	
	h	{32$\bar{1}$0} [or *h'* {3$\bar{1}$20}].	*h* {32$\bar{1}$}	narrow faces replacing the edges of *m* and *a*.
**W*	–	{7520} [or *W'* {7250}]	– {752}	
	c	{0001} . . .	*o* {111}	
	r	{10$\bar{1}$2} . . .	*i* {321}	
	x	{10$\bar{1}$1} . . .	*x* {210}	
	y	{20$\bar{2}$1} . . .	*z* {31$\bar{1}$}	
	s	{2$\bar{1}$11} . . .	*r* {100, 22$\bar{1}$}	

[1] Amer. Journ. Sci., 1899, ser. 4, vol. vii, p. 107; and Zeits. Kryst. Min., 1899, vol. xxxi, p. 333.

[2] 19th Ann. Rep. U. S. Geol. Survey, 1897–8 (1898), part vi, p. 505.

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The green crystals are richer in forms, and exhibit the distribution of faces shown in the projection, fig. 7:—

Bowman.	Dana.		Miller.	
	m	{10$\bar{1}$0}	*a*	{10$\bar{1}$}
	a	{2$\bar{1}$10}	*b*	{2$\bar{1}$1}
	h	{32$\bar{1}$0}	*h*	{32$\bar{1}$}
h'	h_1	{31$\bar{2}$0}	*h*	{31$\bar{2}$}
k'	–	{51$\bar{4}$0}	*k*	{51$\bar{4}$}
**l*	–	{7430}	–	{743}
**W*	–	{7520}	–	{752}
**W'*	–	{7250}	–	{725}
	c	{0001}	*o*	{111}
	r	{10$\bar{1}$2}	*i*	{321}
	x	{10$\bar{1}$1}	*x*	{210}
	y	{20$\bar{2}$1}	*z*	{13$\bar{1}$}
	s	{2$\bar{1}$11}	*r*	{100, 22$\bar{1}$}
	v	{2$\bar{1}$12}	*e*	{411, 110}
	μ	{32$\bar{1}$1}	*u*	{4$\bar{1}$0, 23$\bar{2}$}

narrow faces replacing the edges of *m* and *a*.

small uneven faces, each observed once only.

Of these, *l*, *W*, *W'* are new forms.

The form *l* occurs five times, on four crystals, as a narrow face on the edge *a*/*m*. One of these crystals also bears *μ* on the same side of *a* as *l*, and hence, assuming *μ* to be {2131} (this being commoner than μ_1 {1231}), *l* must be {4870}. No evidence was found of the complementary form {8470}.

The form *k'* occurs once as a narrow face, in combination with *l* but on the opposite side of *a*, the faces present being [*mhamlak'm*]; its symbol must therefore be {1450}. Haidinger[1] mentions a form '*f*' found on a crystal from St. Gothard, which from his figure and description must correspond to this form. It was, however, afterwards omitted by him from the (otherwise similar) figure (fig. 148, pl. xxvii.) in his edition of Mohs' 'Mineralogy' (Edinburgh, 8 5), though it remains ($f(P+\infty)^3$) in the list of forms (vol. ii, p. 74). Apparently on this ground its existence was doubted by Schrauf[2]. Des Cloizeaux figures[3] a corresponding form '*h*^{4},' on the same side of *a* as *μ*, on crystals 'from Cornwall,' and

[1] Edinb. Phil. Journal, 1824, vol. x, p. 148, and pl. v, fig. 16; Isis, 1824, p. 852.

[2] Ber. Akad. Wien, 1870, vol. lxii (2), p. 754. Dana (System, 1892, p. 768, Ref. [4]) mentions *k* {4150} as having been questioned by Schrauf. The latter was however only referring to Haidinger's form (*k'* {1450}), though his symbols cover both *k* and *k'*.

[3] Manuel de Min., vol. ii, p. 484, and pl. lxxiii, figs. 442, 443.

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on both sides of a on crystals 'from Jumilla.' I have, however, been unable to discover the source of these figures. The complementary form $k\{4150\}$ has been found by E. S. Dana on a crystal from Paris, Maine [1]. It does not, however, appear to occur on the present crystals.

The form $h\{2130\}$ is holohedrally developed, as noted by Kenngott [2] and confirmed by Klein [3], on crystals from Poncione della Fibia in the St. Gothard. So also is the new form $W\{5270\}$. The evidence for this

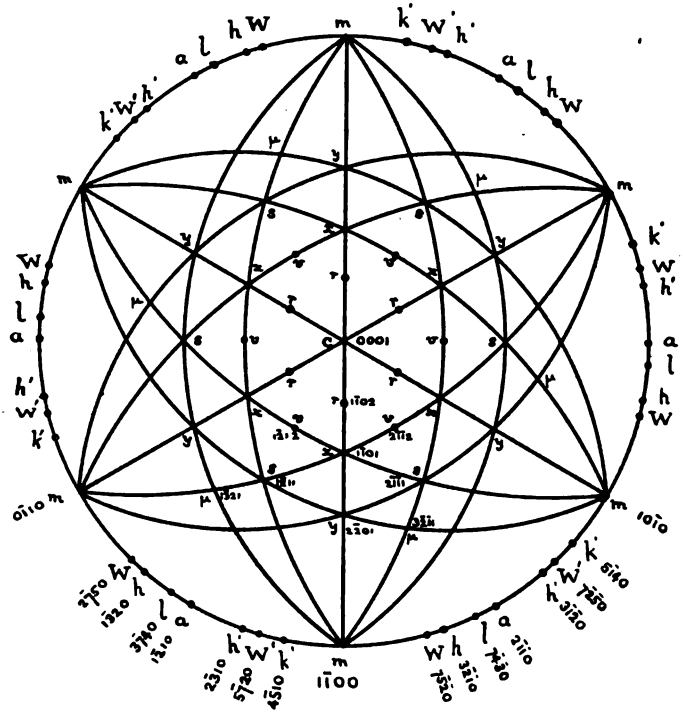

FIG. 7.—Stereographic projection of apatite showing all the forms observed at Haddam Neck.

is derived from two of the greenish crystals showing the following faces in the prism zone:—

(1) [*mlamhamhamlah'mah'm*]. (This is the crystal showing μ, mentioned above.)

[1] Amer. Journ. Sci., 1884, ser. 3, vol. xxvii, p. 480.
[2] Min. d. Schweiz, 1866, p. 353.
[3] Neues Jahrb. Min., 1871, p. 485.

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(2) [*ma W'm Whah'm Wlam*].

W (or *W'*) also occurs on one of the pinkish crystals, combined only with *m* and *a*. Here the two forms cannot be distinguished, as also happens in the case of *h* (or *h'*) occurring with only *m* and *a* upon another pink crystal.

The evidence for the new and doubtful forms is based upon the following measured angles:—

		Edges.	Limits.	Observed mean.	Calculated. $c' = .734603$ (Koksharov).
al	= 1$\bar{2}$10 : 3740	5	4° 8′ – 5° 50′	4° 44′	4° 43′
mh	= 1$\bar{1}$00 : 3$\bar{2}$10	5	18 22 – 19 9	19 5	19 6
mh'	= 1$\bar{1}$00 : 2310	3	18 55 – 19 47		
m {*h* or *h'*}	= 1$\bar{1}$00 : {3$\bar{2}$10 or 2310}	4	18 45 – 19 27		
mk'	= 1$\bar{1}$00 : 4$\bar{5}$10	1	–	11 13	10 54
mW	= 1$\bar{1}$00 : 7$\bar{5}$20	2	14 34 – 16 45	15 38½	16 6
mW'	= 1$\bar{1}$00 : 5$\bar{7}$20	1	15° 28′		
m {*W* or *W'*}	= 1$\bar{1}$00 : {7$\bar{5}$20 or 5$\bar{7}$20}	1	15 49		

The basal plane is bright and gives very perfect reflections, but it appears uneven to the naked eye, owing to its surface being broken by shallow hexagonal pits (2 mm. diam.), which have their edges parallel to the edges *c*/*m*, and are bounded by somewhat curved vicinal faces, *P*, approximating to {2·2̄·0·19}. These faces also occur occasionally upon the edges of the basal plane, as do faces of a form *Q*, near to {22$\bar{0}$7}.

The angles are:—

	Edges.	Limits.	Observed mean.	Calculated.
cP = 0001 : 2·2̄·0·19	5	4° 46′ – 5° 27′	5° 4′	5° 6½′
cQ = 0001 : 22$\bar{0}$7	2	13 9 – 14 8	13 38½	13 37

The faces of *m* are bright and yield excellent reflections; those of *a* are slightly striated parallel to the edge *a*/*m*.

Microcline.

This occurs in stout, greenish-white, opaque crystals (up to 5 cm. high and 4 cm. thick) of the usual habit, which are often very drusy and cavernous, especially on the faces *c* {001}, *x* {10$\bar{1}$}. Minute brilliant

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crystals of albite and crusts of cookeite are sometimes found on the surface.

The following forms are present:—

c {001}, b {010}, m {110}, M {1$\bar{1}$0}, f {130}, z {1$\bar{3}$0}, x {10$\bar{1}$}, y {20$\bar{1}$}, p {$\bar{1}$11}, o {$\bar{1}\bar{1}$1}.

Cleavage flakes parallel to c {001} sometimes show the microcline structure; some are free from twinning and have an extinction angle of about 14°. The extinction angle through a b-cleavage is about +7°; these flakes show an obliquely emergent positive bisectrix.

Some crystals exhibit a cross-hatching, visible to the naked eye, upon the faces c and x.

The specimen carrying colourless beryl, and also a beryl specimen in the British Museum, show a pegmatitic intergrowth of quartz with white microcline.

Albite.

The crystals of this mineral are large and well formed: they are either flattened parallel to b {010} or elongated parallel to x {$\bar{1}$01}, and aggregated in parallel or twin-position to form a group which presents the aspect of a large crystal elongated in the direction of the axis b.

Stout, single crystals are occasionally found (up to a centimetre or more in diameter). (Fig. 8.)

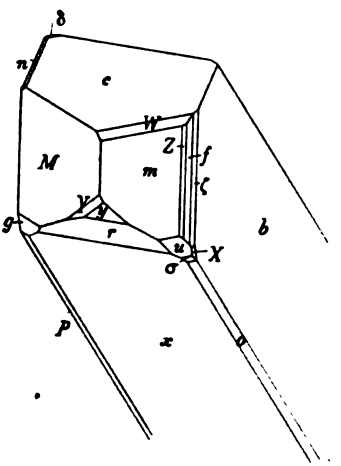

Fig. 8.—Albite from Haddam Neck.

Twinning upon the albite-law is very frequent, but no other kinds of twinning have been observed.

The cleavage-angle bc, obtained from the measurement of a twin-crystal, is 86° 26½′.

The following forms are present:—

b {010}, c {001}.
m {110}, *Z {120}, f {130}, ζ {150}, M {1$\bar{1}$0}.
x {$\bar{1}$01}, r {$\bar{4}$03}, y {201}.
n {021}.
u {22$\bar{1}$}, σ {44$\bar{3}$}, o {11$\bar{1}$}, δ {11$\bar{2}$}, *X {24$\bar{1}$}.
g {22$\bar{1}$}, p {1$\bar{1}\bar{1}$}, *Y {3$\bar{1}\bar{1}$}, *W {111}.

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Of these, *W*, *X*, *Y*, *Z*, do not seem to have been previously recorded; their existence is inferred from the following measurements:—

	Limits.	Edges.	Mean.	Calculated (Dana).	
mW 110 : 111	32° 29′ to 33 51′ rounded	1	33° 10′	32° 28′	Rounded face on edge c/m (on 1 crystal).
yX $\bar{2}01 : \bar{2}\bar{4}1$	52° 57′–53° 40′	2	53 18½	52 56	Narrow face on edge b'/u (on 3 crystals).
uX $\bar{2}21 : \bar{2}\bar{4}1$	—	1	19 51	20 7½	
cX 001 : $\bar{2}\bar{4}1$	—	1	87 58	87 52	
bX 010 : 24$\bar{1}$	—	1	39 8	39 24	
yY $\bar{2}01 : \bar{3}11$	—	1	16 12	16 18	Small bright face on edge y/M' (on 1 crystal).
bZ 010 : 120	—	1	[40 46]	41 21	Very narrow face in zone [b m] (on 1 crystal) [reading by max. illumination].

The mean extinction angles for Na light are:—

on $c\,(001) = 3\frac{1}{2}°$
on $b\,(010) = 19\frac{1}{2}°$.

Good specimens, consisting of aggregations of thin tabular crystals thickly covered with spherules of cookeite, are also found.

Beryl.

The Oxford collection contains four specimens of beryl, which belong to two types. The first of these is represented by three incomplete, and mostly semi-opaque, crystals consisting of a pale rose-pink outer layer (which is occasionally transparent), and a greenish-white core. They have the form of hexagonal prisms, m {10$\bar{1}$0}, terminated by the basal plane, and bearing faces of a pyramid, s {11$\bar{2}$1} on the corners. They range up to 8 cm. in diameter, and are remarkable for the possession of fairly perfect cleavages, parallel to m {10$\bar{1}$0} and c {0001}, and sometimes enclose crystals of albite and tourmaline. To the second type belongs a nearly colourless crystal, about 2 cm. in diameter, embedded among grey quartz crystals. It is almost devoid of smooth faces and difficult to decipher, but an acquaintance with the British Museum specimen described below, leads to the recognition

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of its two bright faces as belonging to m {10$\bar{1}$0}, while the dull, rough faces probably belong to s {11$\bar{2}$1}, n {31$\bar{4}$1}, p {10$\bar{1}$1}. The basal plane c {0001} is probably also present, but is almost hidden by the surrounding quartz crystals. The habit differs somewhat from the crystal figured, being flat-pyramidal owing to the reduction of the prism faces to small rhombs bounded by n {31$\bar{4}$1}.

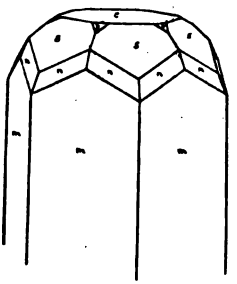

Fig. 9.—Beryl from Haddam Neck.

In the British Museum are two specimens of beryl from Haddam Neck, which are both labelled as containing caesium [1]. One of these is a large, stout prism of very pale pink colour, corresponding to the first type, and enclosing small prisms of the usual tourmaline and a small fragment of a brown mineral, probably garnet. The other, which represents the second type, is a nearly colourless hexagonal prism (fig. 9), 1·5 cm. in diameter and 2·5 cm. long, with pyramid faces, associated with grey quartz, white microcline, pink and green tourmaline and albite, on 'graphic' microcline-pegmatite. The faces belong to the following forms:—

Dana.		Miller.
m {10$\bar{1}$0}	. . .	a {10$\bar{1}$}
c {0001}	. . .	o {111}
s {11$\bar{2}$1}	. . .	r {100, $\bar{1}$22}
n {31$\bar{4}$1}	. . .	– {203, 423}
p {10$\bar{1}$1}	. . .	p {120}

The basal plane is very uneven, with ridges and pits, but bright; the prism is smooth and brilliant; of the pyramids, s is somewhat pitted, while n is usually dull but with some bright areas. The faces of the latter form generally show a rounding-off in the direction of s. The form p only occurs as minute triangular faces on the corners scs. The crystal resembles the colourless beryl known as 'goshenite' from Goshen, Massachusetts.

Quartz.

Quartz occurs both in nearly colourless and in somewhat smoky crystals: those of the former variety are curiously flattened parallel to a pair of

[1] Mr. Lazard Cahn, through whom the specimens were obtained, informs me that they were tested by Prof. Penfield and found to contain caesium.

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prism faces. Only one side of such tabular crystals has the faces regularly developed, the faces at the back being interrupted, uneven, and drusy, with the result that the specimens (though frequently doubly terminated and bounded on all sides by faces) present the appearance of flakes split off from the side of a large normally developed crystal.

The smoky crystals are regular prisms with pyramidal termination, the faces of which are sometimes rhombohedrally developed. The surface of the crystals is often encrusted with cookeite.

Cookeite.

Small globular masses (up to 5 mm. diam., but usually not above 1 mm.) occur, having the following characters. They are of a yellowish-white colour and are composed of silvery radial plates with hexagonal outline. These are seen under the microscope to be divided radially into biaxial sectors, each striated perpendicular to the edge of the hexagon, and showing a normally emergent bisectrix of wide axial angle, with axial plane perpendicular to the striations and positive birefringence. The axial angle diminishes towards the centre, and the central part is uniaxial, with the optic axis normal and weak positive double refraction. These characters agree with those of cookeite as given by Penfield[1].

The cookeite occurs chiefly on the surface of albite and quartz crystals and on the prisms of lepidolite. It does not seem to occur much on the tourmaline, and where it does so the surface of the latter underneath is quite fresh and smooth, so that the cookeite would not here appear to have been derived from the decomposition of rubellite, as has been suggested by Brush[2] in regard to cookeite from Hebron and Paris, Maine.

The minerals are so intimately mixed that it is hard to say of what the cookeite is a decomposition product, but it may be perhaps derived from the micas.

The blowpipe characters agree with those given for cookeite.

Fluor.

The fluor is dark reddish-brown, and sometimes shows faces of the octahedron. None of the fragments show any of the matrix.

[1] Amer. Journ. Sci., 1893, ser. 3, vol. xlv, p. 393.
[2] Ibid. 1866, ser. 2, vol. xli, p. 247.

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Besides this brown variety, I have recently seen a specimen consisting of small pale-green, opaque, somewhat drusy octahedra (4 mm. diam.) showing a purplish tinge in parts, associated with spherules of cookeite and a few fibres of the pink muscovite.

Microlite.

I have had no opportunity of seeing specimens of the microlite, as there is none in the Oxford collection and it is also wanting in the British Museum. Mr. Schernikow, however, says that it was found 'sparingly, associated with the other minerals. A few good crystals, perhaps ¼ inch in diameter, were obtained, but most of them were broken.'

Mr. Cahn tells me that the mineral was identified as microlite by Professor Penfield, and that the specimens occur in the pink beryl or in albite.

Columbite.

Columbite is stated to occur in the Haddam Neck quarries in association with beryl. The crystals are small but well defined, with brilliant faces, and differ thus from the columbite from Haddam, where the crystals are usually large and coarse.

Mode of Occurrence and Paragenesis.

In their mode of occurrence and characters some of the minerals from Haddam Neck show a remarkable resemblance to those from the well-known occurrences in the pegmatite veins of Maine and other parts of New England. The large crystals of muscovite surrounded by a border of lepidolite, for example, correspond exactly with similar specimens from Auburn, and some of the latter show, outside the lepidolite, a small amount of a rhombic tesselated mica similar to the pink fibrous muscovite which forms such a marked feature of the Haddam Neck specimens.

The regular intergrowth of greenish-white muscovite with massive quartz, which is visible on more than one of the specimens from Haddam Neck, finds its exact equivalent in a specimen in the British Museum, showing beryl from Goshen, Massachusetts. The beryl on the same specimen (the colourless 'goshenite') also strongly resembles the same mineral from Haddam Neck, the presence of caesium in which indicates an affinity with the beryls of Norway and Hebron in Maine, in which from 1·66–3·6 per cent. of Cs_2O have been found by Penfield and Harper and by Wells, respectively.

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Judging from the relative positions of Haddam and Haddam Neck and from the information I have been able to obtain, it seems probable that the pegmatite veins traversing gneiss, which are the source of the minerals in both places, form part of the same system, though the minerals from the recently opened felspar quarries on Haddam Neck differ somewhat from those of the old occurrences described as Haddam. Thus the tourmaline from the latter occurs as stout black prisms, and the well-known chrysoberyl of Haddam does not seem to have been so far discovered at the new quarries, although it is mentioned as having been found on both banks of the river [1].

In regard to the order of formation of the minerals but little can be said, as the different species are intimately mixed together in a way which suggests that they were all formed more or less contemporaneously. The quartz was probably one of the last-formed minerals, as it frequently encloses complete crystals of tourmaline and masses of the pink fibrous mica. It forms in some cases a pegmatitic intergrowth with microcline, and sometimes also encloses flakes of greenish muscovite in parallel position, forming a somewhat analogous structure. The micas perhaps represent an early stage in the crystallization. Among themselves they never show any deviation from the order, greenish-white muscovite—lepidolite—fibrous muscovite. Minute scales of lepidolite, dispersed through the apatite crystals, are found after solution of the latter in acid. Microcline is probably a late formation, contemporaneous with the quartz, and sometimes encloses tourmaline and lepidolite.

In conclusion, I wish to express my thanks to Mr. Schernikow for his kindness in supplying me with information as to the locality and occurrence of the specimens, to Professor Berwerth for allowing me to examine the collection of micas in the Museum at Vienna, and to Mr. Fletcher for similar permission in respect of the specimens in the British Museum. I also wish to thank Professor Penfield for kind hints in connexion with the analysis, and Professor Miers for his kind advice throughout the work.

[1] Amer. Journ. Sci., 1822, ser. 1, vol. iv, p. 53; 1823, ser. 1, vol. vi, p. 220.

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DESCRIPTION OF FIGURES 1-5 (PLATE IV).

Fig. 1.—Cleavage flake of the pink tesselated muscovite, showing the arrangement of the rhombs in twin position (×14).

Fig. 2.—A fibre of the pink muscovite. (The convergence of the faces is exaggerated.) $r = \{552\}$, $S = \{551\}$.

Figs. 3 and 4.—Flakes from crystals of muscovite with border of lepidolite (*M*, muscovite; L_m, macrodiagonal-; and L_b, brachydiagonal-lepidolite). The areas are shaded parallel to their axial planes. Unshaded areas of the border do not extinguish, owing to overlapping.

Fig. 3 shows a narrow band of L_m in parallel position on *M*, with areas of L_b outside it (×8).

Fig. 4 shows L_m in parallel position, and L_b in twin-positions, on *M* (×10). $m = \{110\}$, $b = \{010\}$.

Fig. 5.—Flake from a crystal of macrodiagonal-lepidolite showing the arrangement of the fibrous border. $m = \{110\}$, $b = \{010,\}$ $Q = \{130\}$. The areas II are in the extinction-position (×5).

(Figs. 6-9 in the text.)

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On the remarkable problem presented by the crystalline development of Calaverite.

By G. F. Herbert Smith, M.A., F.G.S.
With a Chemical Analysis by G. T. Prior, M.A., F.G.S.
Assistants in the Mineral Department of the British Museum.

[Read March 19 and June 18, 1901].

THE validity of Haüy's great law of the rationality of intercepts — better known as the law of rational indices—or its equivalent, the law of homogeneity of arrangement of the ultimate particles in a crystalline structure, has as yet never been seriously called into question: nevertheless, in the crystals of the telluride of gold, calaverite, we find characters which are to all appearance at variance with this law. As far as the author is aware and can ascertain, no difficulty of a precisely similar kind has ever been encountered before[1]. Certain substances do, indeed, display the so-called optical anomalies; but these are, as was first established by Mallard, in reality in strict accordance with the actual crystalline arrangement. In calaverite we are confronted with a problem of a different nature: here, if we pay attention merely to the morphological development of the faces, we immediately conclude that the crystals have the symmetry of the monoclinic system; there is evidently an axis of digonal symmetry parallel to the prism edge, and on many crystals a face may be noticed perpendicular to this edge, and, save in those which are obviously twins, there are no re-entrant angles[2] to suggest that the crystals are other than simple; their opacity prevents any optical investigation. When, however, we proceed to assign indices to the forms we find that with the exception of a few, to which by a suitable choice of the crystallographic axes and parametral plane we necessarily give simple indices, all the forms receive symbols of great

[1] The faces with high indices but simple mutual relations, lying in the same zone, in such a mineral as meneghinite may possibly be due to a similar cause, but in this case the common faces present no difficulties at all.

[2] Re-entrant angles do occur in the prism zone, but are due to its oscillatory and striated character.

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and unsatisfactory complexity. So few, indeed, are the forms which receive anything approaching to simple indices that it is difficult to believe that this interpretation adequately represents the actual symmetry of calaverite. It will be shown in the course of this paper that the faces do possess zonal relations and do obey the law of simple anharmonic ratios in every zone, but they cannot be referred to a single lattice. In fact there appear to be as many as five distinct lattices, which are incongruent but not independent. The exact relations between them and the possible meaning of such a remarkable conjunction are discussed below (pp. 140–1).

Until quite recently practically nothing was known of the crystallographic characters of calaverite. The name was given by Genth [1] to a massive telluride of gold from the Stanislaus Mine, Calaveras County, California. The material from Cripple Creek, Colorado, analysed by Dr. W. F. Hillebrand, was, indeed, in part well crystallized, but so small and unsymmetrically developed were the crystals that Professor Penfield [2], to whom they were sent for examination, was unable to determine with certainty even the system of crystallization, and could only conclude that the crystals were probably triclinic and near sylvanite in their angles and axial ratios. Better material having since that time become available, Professor Penfield and Mr. W. E. Ford [3] have recently published a paper in which they place calaverite in the monoclinic system, but confess that the symbols which must be assigned to most of the faces are inexplicably high.

During the past two years and a half the Mineral Collection of the British Museum has been enriched by the acquisition, mainly through the kind consideration of Mr. Milton Moss, of a fine suite of specimens from the Cripple Creek District, Colorado. Conspicuous among these are numerous brilliant, yellowish crystals, which were stated to be calaverite. With the view of establishing their identity and determining the crystallographic characters of this mineral, a goniometric examination of the best crystals was begun by the author early in November, 1900, and continued almost without interruption for some months, during which time more material came to hand. The preliminary results of the investigation were discussed at the meetings of the Society held on

[1] Amer. Journ. Sci., 1868, ser. 2, vol. xlv, p. 314.

[2] 16th Annual Report U. S. Geol. Survey, 1894-5 (1895), pt. ii, pp. 135-6; also Amer. Journ. Sci., 1895, ser. 3, vol. l, p. 131.

[3] Amer. Journ. Sci., 1901, ser. 4, vol. xii, pp. 225-46; a German translation appeared in Zeits. Kryst. Min., 1902, vol. xxxv, pp. 430-51.

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March 19 and June 18, 1901. The brief notice of the earlier meeting which appeared in 'Nature[1]' attracted the attention of Professor Penfield, and he communicated with the present writer, who in reply gave a more detailed account of his conclusions; in consequence a paragraph[2] referring to them was inserted in the paper of Penfield and Ford already mentioned.

In the course of this investigation measurements were made of no fewer than forty-nine crystals, of which nineteen were removed from the matrix for the purpose and thirty had been already isolated. Nine crystals were taken from a specimen stated to have come from the Midget Mine, Gold Hill; one from a specimen from the Doctor Jackpot Mine, Raven Hill, and fifteen isolated crystals came from the same mine; four isolated crystals came from the Victor Mine, Bull Hill; and eight isolated twin crystals from the Elkton Mine, Raven Hill: the exact localities of the remaining specimens are not stated on the labels. Twenty-six are what may be called simple crystals, and twenty-three are crystals twinned according to ordinary laws; of the twenty-six simple crystals seventeen are left-handed and nine right-handed, in the sense employed by Penfield and Ford. They are associated with quartz, iron-pyrites, fluor and kaolin, and are, when on the matrix, firmly embedded in the gangue. Consequently crystals terminated at both ends are exceedingly rare; indeed only one such instance was noticed, and that in the case of one individual of a cross twin; in another case, where faces occur at the lower end they really belong to the second individual of a twin. When fresh, the crystals are silver-white in colour, but become more or less deep bronze-yellow on exposure.

The crystals differ considerably in size but are very similar in appearance, the cross-section varying from a narrow oblong to a square (see figs. 1 and 2); those removed from the matrix are small, with a cross-section of about $0{\cdot}5 \times 0{\cdot}5$ mm., in the case of the smallest measured of $0{\cdot}2 \times 0{\cdot}2$ mm.; the isolated crystals are very much larger, some being as much as 7 mm. in length with a breadth varying from 1–5 mm. Many of the large crystals are skeletal, with a remarkable development of internal faces which are all consistent with the development of the exterior; it is not uncommon to find pits on a large face lined with faces in harmony with the crystalline development. Many crystals which, judged from the exterior, appear to be compact are found on fracture to be more or less hollow.

The crystals are prismatic in habit. The prism zone is so much

[1] Nature, 1901, vol. lxiii, p. 554.

[2] Loc. cit., p. 241.

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striated parallel to its edge that a definite single image rarely occurs corresponding to any particular face; the terminal faces, on the other hand, give good definite reflections in most cases, although many of the faces, even on the large crystals, are so minute that when viewed through the microscope of low power, into which the telescope of the goniometer may be converted, only a speck of light is visible and no certain contour is discernible. The figures, though intended to be representative, have been drawn from actual crystals; in figs. 1, 2, 4, 5, and 6 the line

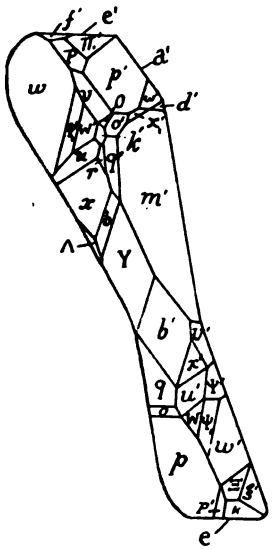

FIG. 1.

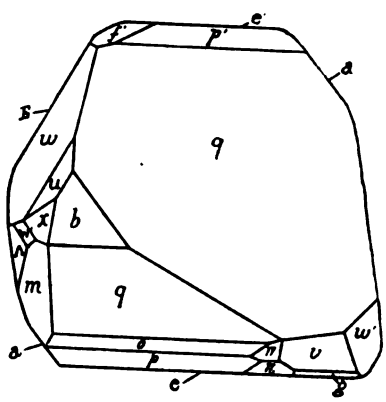

FIG. 2.

Untwinned crystals.

of sight is supposed to be parallel to the edge of the prism. The crystal drawn in fig. 1 has a cross-section of $3{\cdot}5 \times 0{\cdot}7$ mm. and possesses no fewer than sixty-two terminal faces representing forty-two different forms. Nearly half of these are so minute that it was impossible to include them in the drawing. The proportionate size even of the smaller faces given in the figure had necessarily to be somewhat exaggerated. This figure is typical of all those with many faces; a few faces, such as *p*, *o*, *q*, *b*, *y*, &c., are comparatively large, but the remainder, situated at the edges or on the corners of the large faces, are almost infinitesimal in size; nevertheless they give measurable, if very faint, images. The crystal drawn in fig. 2 has a cross-section of $2{\cdot}2 \times 2{\cdot}2$ mm. It is

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remarkable for the unusual number of definite faces in the prism zone which give distinct images.

The crystals are very brittle, but exhibit no cleavage. Their fragility is so great that many of the isolated crystals are broken in parts (cf. figs. 4, 5, and 6).

In carrying out the examination of these complex crystals the author had at his disposal an instrument conveniently adapted to the purpose in the three-circle form of goniometer[1] designed by him, whereby the zonal relations of the terminal forms can be determined by direct observation. It may here be repeated that the method of using this instrument is to adjust the edge of some prominent zone—in this case the prism zone—parallel to the axis of the third circle, C[2], and to make measurements from any pole in this zone which is crystallographically possible, but does not necessarily represent an existing face. For any terminal face the readings of the circles A and B, duly corrected for the zero reading, give respectively the polar distance and the azimuth. The azimuths when measured from such a pole must, in the case of a simple crystal, obey the law of rational anharmonic ratios, and we have, therefore, a convenient method of determining the indices of any terminal face as the intersection of two known zones.

As has been already stated, the prism zone of calaverite is invariably striated; this, of course, does not in any way prevent, but on the contrary tends to facilitate, the accurate adjustment of its edge parallel to the axis of C. On the other hand, no face is found to give a sufficiently well defined image which can invariably serve as pole of reference, and any such pole had to be determined from the intersection of a cross zone with the prism zone. Fortunately there happens to occur on all the measured crystals, with the exception of a few cross twins, a markedly prominent zone, which contains at least two, and usually three or four, well developed faces, giving bright and distinct reflections. The adjustment of this zone could, therefore, be made with considerable certainty, and, indeed, whenever it was deemed necessary to re-measure any crystal, there was very close agreement between the two sets of readings; any discrepancy is generally due to a slight want of parallelism in the prism zone, or, if it occurs in a few particular readings, to a want of definition

[1] This Magazine, 1899, vol. xii, pp. 175–82; a translation appeared in the Zeits. Kryst. Min., 1900, vol. xxxii, pp. 209–16. Cf. also this vol., p. 75.

[2] This is the same notation as that employed in the papers mentioned above: A is the horizontal circle, whose axis is fixed in space; B the vertical circle, whose axis lies in a horizontal plane; and C the third circle, whose axis may take any direction in space.

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in the reflected images. Unless the corresponding image is much striated any reading may be regarded as accurate within 5′; a point to which we refer later. The point of intersection of the above-mentioned zone with the prism zone served as pole of reference for the whole of the crystals measured, with the exception of the twins alluded to. These measurements are given in Table I.

In this table the whole of the observations made on forty-two crystals are incorporated, and have been duly weighted in deducing the mean values; the remaining seven crystals examined, all cross twins, do not possess the particular cross zone sufficiently well developed for the accurate determination of the pole of reference. The symmetry revealed by the measurements is discussed later, but we may mention here that the fundamental constants and the indices of the forms have been calculated by the method of least squares, from the angles marked with an asterisk, on the hypothesis that the symmetry is triclinic, and becomes pseudo-monoclinic owing to twinning about an axis parallel to the edge of the prism zone. The symbols given in the first column are the indices which the faces receive when referred to the principal lattice, on which most of the large and prominent faces lie. Many which receive complex indices, when referred to this lattice, have simple indices, when referred to a second; these symbols are given in the second column. As will be seen below, a few, such as Y and μ, which cannot be referred to either of these lattices, lie on a third. The prism zone is common to all three. The constants of the second lattice are computed from the calculated values in Table I; those of the third lattice from the values calculated for the prism zone and from the mean observed azimuth and distance of J, namely, 90° 0′ and 105° 11′½.

The fundamental constants of the three lattices are :—

$\mathbf{T}_1$. First and principal (triclinic) lattice :

$$a : b : c = 2{\cdot}0013 : 1 : 1{\cdot}1713;$$

$$a = 88° 58′,\ \beta = 100° 39′,\ \gamma = 96° 19′;$$

$$010 : 001 = 94° 59′,\quad 001 : 100 = 79° 54½′,\quad 100 : 010 = 84° 41′.$$

$\mathbf{T}_2$. Second (triclinic) lattice :

$$a : b : c = 2{\cdot}0990 : 1 : 1{\cdot}2231;$$

$$a = 72° 14′,\ \beta = 104° 48′,\ \gamma = 108° 37′;$$

$$010 : 001 = 104° 7′,\quad 001 : 100 = 79° 54½′,\quad 100 : 010 = 74° 48½′.$$

$\mathbf{M}_2$. Third (monoclinic) lattice :

$$a : b : c = 1{\cdot}9868 : 1 : 1{\cdot}1634;$$

$$\beta = 100° 5½′.$$

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TABLE I.

Measurements from e (101).

Form.				Calculated Values.		Observed Means.		Edges.	Limits of Observation.				Remarks. Characters of faces and images.
	T_1	T_2	M_3	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.		Distance.		
				° ′	° ′	° ′	° ′		° ′	° ′	° ′	° ′	
e	101	...	...	0 0	0 0	0 0	0 1	33	...	...	359 41 –	0 30	Small; image distinct.
e_1	705	...	...	,, ,,	7 36½	,, ,,	7 35	2	...	...	7 23,	7 47	Striated.
e_2	302	...	...	,, ,,	9 15								
e_3	201	...	...	,, ,,	16 8	,, ,,	?	...	...	...	10° – 17°		,,
e_4	401	...	...	,, ,,	30 57								
e_5	501	...	...	,, ,,	34 42	,, ,,	?	...	...	...	30° – 38°		,,
a	100	...	...	,, ,,	52 18½	,, ,,	52 28	42	...	...	51 30 –	53 9	Often large; single image.
E_{12}	10.0.$\bar{1}$	...	...	,, ,,	62 8	,, ,,	62 11½	8	...	...	61 20 –	62 38	Striated.
E_{11}	60$\bar{1}$	...	...	,, ,,	68 44	,, ,,	69 7	42	...	...	68 15 –	69 58	,,
E_{10}	25.0.$\bar{8}$	...	...	,, ,,	75 48	,, ,,	75 54	8	...	...	75 42 –	76 11	,,
E_9	11.0.$\bar{3}$	...	...	,, ,,	78 50½	,, ,,	78 41	10	...	...	78 1 –	79 32	,,
E_8	30$\bar{1}$	...	...	,, ,,	84 13								
E_7	50$\bar{2}$	...	...	,, ,,	89 41	,, ,,	?	...	...	...	84° – 96°		Much striated and oscillatory.
E_6	20$\bar{1}$	...	...	,, ,,	96 58½								
E_5	905	...	...	,, ,,	100 33								
E_4	70$\frac{1}{4}$	...	...	,, ,,	101 31	,, ,,	101 0	16	...	...	99 58 – 102 42		Striated.
E_3	807	...	...	,, ,,	115 40	,, ,,	115 20	5	...	...	114 39 – 115 53		,,
E	10$\bar{1}$	...	...	,, ,,	119 40½	,, ,,	119 19½	24	...	...	118 11 – 120 6		Distinct face and image.
E_1	30$\bar{4}$	...	...	,, ,,	127 18	,, ,,	127 5½	8	...	...	125 48 – 127 52		Striated.
E_2	103	...	...	,, ,,	141 8½	,, ,,	140 28	6	...	...	140 18 – 140 51		,,
o	00$\bar{1}$	...	...	,, ,,	152 24	,, ,,	152 18	44	...	...	151 24 – 152 40		Small; image distinct.
e_7	10$\bar{2}$	...	...	,, ,,	167 44								
e_8	7.0.$\bar{12}$	...	...	,, ,,	170 0	,, ,,	?	...	...	...	168° – 171°		Striated.

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η	21·4·3	...	...	21 19	69 25	21 9	69 18	1	... ...	... ...	Small; image good.
β	69·20·5	310	...	31 28½	65 53	31 38	66 2	2	31 37, 31 39	65 59, 66 5	Small; images good.
χ	310	...	...	36 30½	61 33½	36 32½*	61 40	1	... ...	... ...	Small; image good.
γ	52$\bar{1}$	...	...	,, ,,	77 39½	,, ,,	77 55	1	... ...	... ...	Minute; image poor.
σ	21$\bar{1}$	...	...	,, ,,	95 56	,, ,,	96 1	1	... ...	... ...	,, ,,
ξ	32$\bar{3}$	...	...	,, ,,	118 6½	,, ,,	118 2½	6	36 20 – 36 42	112 48 – 118 15	Small; images distinct.
ϖ_1	112	...	...	,, ,,	126 51½	...	...	...	... ...	... ...	See Table III.
ρ_1	59·20·5	521	...	39 7	55 32	39 12	55 11	1	... ...	... ...	Minute; image poor.
ρ	49·20·5	210	...	,, ,,	71 1	39 9	71 1	12	38 22 – 39 25	70 42 – 71 54	Small; images distinct.
Z	39·20·15	32$\bar{1}$	...	,, ,,	89 54	39 12	89 52	2	39 0, 39 24	89 50, 89 54	Minute; images poor.
K	29·20·25	11$\bar{1}$	...	,, ,,	108 48	39 0	108 45	1	... ...	... ...	,, image poor.
K_1	19·20·35	123	...	,, ,,	124 19½	...	...	...	... ...	... ...	Not observed; a possible plane of twinning.
α	521	...	...	46 34	50 22	46 30½*	50 27	1	46 13 – 46 48	... ...	Minute; image poor.
ϕ	210	...	...	,, ,,	66 31½	,, ,,	66 33	9	,, ,,	66 11 – 66 59	Small; images distinct.
θ	32$\bar{1}$	...	...	,, ,,	87 41½	,, ,,	87 47½	9	,, ,,	87 20 – 88 7	,, ,,
w	11$\bar{1}$	...	...	,, ,,	109 28½	,, ,,	109 27½	51	,, ,,	109 11 – 109 48	Common face: usually small; images good.
Δ	39·20·5	32$\bar{1}$	...	50 27½	59 7	50 35	59 21½	2	50 14 – 50 49	59 18, 59 25	Minute; images poor.
Λ	29·20·5	110	...	,, ,,	79 48½	,, ,,	79 27	7	... ...	79 5 – 79 56	Small; images fair.
Ψ	19·20·15	12$\bar{1}$	...	,, ,,	103 25	,, ,,	103 35	7	... ...	103 23 – 103 40	,, ,,
R_2	11·6·3	...	...	55 53	52 20	54 35	52 20	1	... ...	... ...	Minute; image poor.
R_3	531	...	...	,, ,,	58 6½	,, ,,	59 10	1	... ...	... ...	,, ,,
R_1	563	...	...	,, ,,	97 12½	55 0	96 26½	5	54 48 – 55 19	96 20 – 96 31	Small; images fair: indices uncertain.
R	23$\bar{2}$	...	...	,, ,,	105 26	55 55	105 31	1	... ...	... ...	Minute; image poor.
d_1	211	...	...	61 30½	36 12½	61 31½*	37 0	1	61 12 – 61 50	... ...	Minute; image bad.
d	321	...	...	,, ,,	53 57	,, ,,	54 2½	15	,, ,,	53 50 – 54 15	Small; images distinct.
τ_1	541	...	...	,, ,,	63 55	,, ,,	63 15	1	,, ,,	... ...	Minute; image bad.

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TABLE I (continued).

MEASUREMENTS FROM e (101).

Form.				Calculated Values.		Observed Means.		Edges	Limits of Observation.		Remarks, Characters of faces and images.
	T_1	T_2	M_3	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.	
				° ′	° ′	° ′	° ′		° ′ — ° ′	° ′ — ° ′	
m	110	...	...	61 30½	75 54	61 31½	75 54*	63	61 12 — 61 50	75 29 — 76 26	Very common and large; images good.
r	34Ī	...	...	,, ,,	89 16½	,, ,,	89 34	1	,, ,,	... ...	Minute; image poor
n	12Ī	...	...	,, ,,	102 43	,, ,,	102 38½	39	,, ,,	102 28 — 102 56	Common and fairly large; images good.
n_1	14$\bar{3}$	...	...	,, ,,	114 53	,, ,,	113 10	1	,, ,,	... ...	Minute; indices doubtful.
M	01Ī	...	...	,, ,,	125 5	,, ,,	125 5	17	,, ,,	124 54 — 125 18	Small; images fair.
ω	29.20.15	111	...	67 8½	47 10½	67 29½	47 10	8	66 44 — 69 9	46 32 — 47 26	Small; images poor.
x_1	19.20 5	121	...	,, ,,	66 52½	,, ,,	66 53	2	,, ,,	66 45, 67 1	Minute; ,,
x	9.20.5	010	...	,, ,,	94 10	,, ,,	94 8½	26	,, ,,	93 24 — 94 36	Common and fairly large; images fair.
X	Ī.20.I5	I2Ī	...	,, ,,	119 48	,, ,,	119 54	3	,, ,,	119 44 — 120 0	Minute; images poor.
Ω	ĪI.20.25	I1Ī	...	,, ,,	187 0½	,, ,,	186 55	3	,, ,,	186 55 — 187 15	,, ,,
N_2	471	...	...	72 41	75 56½	72 12	76 18	1	... ...	... ...	,, Image bad.
N_1	870	...	...	,, ,,	84 9	73 18	85 8	1	... ...	... ...	,, ,,
N	477	...	...	,, ,,	138 1½	72 55	138 30	1	... ...	... ...	,, ,,
i	323	...	...	82 6½	82 14	82 7½	82 14½	18	81 30 — 82 40	82 8 82 40	Small; images poor.
p	111	...	...	,, ,,	43 38½	,, ,,	43 39*	76	,, ,,	43 17 — 44 2	Very common and large; images good
s	343	...	...	,, ,,	52 8	,, ,,	52 5	2	,, ,,	51 55, 52 15	Small; images fair.
o	121	...	...	,, ,,	62 55½	,, ,,	62 55*	61	,, ,,	62 11 — 63 43	Very common and large; images good.
q	141	...	...	,, ,,	76 22	,, ,,	76 21½*	60	,, ,,	76 0 — 76 36	Very common and large; images
l	161	...	...	,, ,,	81 18½	,, ,,	81 14	1	,, ,,	... ...	Minute; image poor. [usually good.
b	010	...	...	,, ,,	91 30	,, ,,	*91 30½	57	,, ,,	91 8 — 92 15	Very common and large; images

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L	161	...	...	,,	,,	101 36	,,	,,	101 22	2		,,	,,	101 16,	101 28	Minute; images poor.
Q	141	...	...	,,	,,	106 25½	,,	,,	106 25½	7		,,	,,	106 12 –	106 39	,, images fair.
y	121	...	...	,,	,,	119 24	,,	,,	119 27	20		,,	,,	119 17 –	119 54	Small; ,,
P	111	...	...	,,	,,	137 45	,,	,,	137 45	12		,,	,,	137 11 –	137 53	,, ,,
I	323	...	...	,,	,,	148 36	,,	,,	148 30	2		,,	,,	148 25,	148 35	Minute; images poor.
A	5.32.3	...	...	87	50½	90 9½	87	27	90 26	4	87	18 –	87 40	90 14 –	90 33	,, ,,
Π_2	29.20.35	112	...	89	0	29 21	89	6	29 30	1	88	24 –	90 0	...	...	,, image poor.
Π_1	19.20.25	123	...	,,	,,	38 58½	,,	,,	39 2	4		,,	,,	38 42 –	39 12	Small; images fair.
Π	9.20.15	011	...	,,	,,	55 15½	,,	,,	55 26½	7		,,	,,	54 47 –	55 37	,, ,,
ψ	1.20.5	121	...	,,	,,	81 24½	,,	,,	81 38	6		,,	,,	81 15 –	82 14	Minute; images poor.
λ	11.20.5	110	...	,,	,,	111 22	,,	,,	111 27	2		,,	,,	111 26,	111 28	,, ,,
δ	21.20.15	321	...	,,	,,	133 2	,,	,,	132 52	2		,,	,,	132 40,	133 4	,, ,,
π	31.20.25	211	...	,,	,,	145 53	...		...	...	...	..		...	...	Given by Penfield and Ford.
Y	5.24.3	...	010	89	46½	89 42½	90	0[1]	90 0[1]	23			90 12		90 8	Common and large; images good.
J	11.24.3	...	141	,,	,,	104 54	,,	,,	105 11½	6	...		...	105 4 –	105 16	Minute; images fair.
O_1	141	...	...	93	37½	84 56½	93	22	85 5	1	...		...	...	...	Minute; image poor.
O	120	...	...	,,	,,	100 19½	93	30	100 17	1	...		...	...	...	,, ,,
C_1	9 10.15	...	...	95	55½	85 24½	96	1	85 37	1	95	10 –	96 48	...	...	,, ,,
C_2	4.15.5	...	...	,,	,,	81 39½	,,	,,	82 14	2		,,	,,	82 8,	82 20	,, images poor.
C	350	...	...	,,	,,	102 0½	,,	,,	102 11	9		,,	,,	101 35 –	102 23	Small; ,,
C_3	41.60.5	...	...	,,	,,	106 52½	,,	,,	106 57	2		,,	,,	106 53,	107 1	Minute; ,,
C_4	28.35.5	...	...	,,	,,	110 11	,,	,,	110 12	1		,,	,,	...	...	,, image poor.
C_5	11.10.5	...	...	,,	,,	126 59	,,	,,	127 15	1		,,	,,	...	...	,, ,,
C_6	27.20.15	...	...	,,	,,	135 39½	,,	,,	135 22	1		,,	,,	...	...	,, ,,
H_1	142	...	...	99	20	74 27½	98	52	74 24	1	...		...	...	...	,, ,,
H_2	11.16.1	...	...	,,	,,	100 46½	98	51	100 48	2	98	50,	98 52	100 47,	100 49	,, images poor.
H	340	...	...	,,	,,	104 25½	99	40	104 46	2	99	30,	99 50	104 40,	104 52	,, ,,

[1] The mean values of the co-ordinates of Γ cannot be determined because there is no possibility of ascertaining whether a measurement is greater or less than a right angle.

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TABLE I (*continued*).

Measurements from *e* (101).

Form.				Calculated Values.		Observed Means.		Edges.	Limits of Observation.		Remarks. Characters of faces and images.
	T_1	T_2	M_2	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.	
				° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′	
h_1	7·15·5	...	...	100 27½	85 12	99 57	85 49	1	... ...	... ...	Minute; image poor.
h	$\bar{4}50$	...	...	,, ,,	105 12	100 43	105 6	2	100 40, 100 46	104 82, 105 40	,, images poor.
h_2	$\bar{1}3·10·5$	...	...	,, ,,	128 50½	100 50	128 30	1	... ...	... ...	,, image poor.
e	$\bar{1}1·24·9$	...	$\bar{1}41$	101 12	83 16½	101 19½	82 7	1	101 5 – 101 40	... ...	,, image poor.
μ	$\bar{1}7·24·3$	...	$\bar{1}20$	,, ,,	98 25½	,, ,,	98 40½	19	,, ,,	98 31 – 98 47	Small; images fair.
ζ	$\bar{2}3·24·3$	...	$34\bar{1}$	,, ,,	112 30	,, ,,	112 50	3	,, ,,	112 40 – 112 55	Minute; ,,
f	112	...	...	104 52	29 28	104 51½	29 30	25	104 24 – 105 35	29 5 – 29 42	Small; images good.
g	123	...	...	,, ,,	38 45½	,, ,,	38 48½	11	,, ,,	38 37 – 39 3	,, images fair.
r	011	...	...	,, ,,	54 11½	,, ,,	54 17	6	,, ,,	54 12 – 54 24	,, ,,
r	$\bar{1}21$	...	...	,, ,,	78 51½	,, ,,	78 48½	23	,, ,,	78 20 – 79 4	,, ,,
r_1	$\bar{4}51$	...	...	,, ,,	96 37½	,, ,,	96 35	1	,, ,,	... ...	Minute; image poor.
t	$\bar{1}10$	...	...	,, ,,	108 7½	,, ,,	107 58	23	,, ,,	107 25 – 108 22	Common, but not large; images fair.
D	$32\bar{1}$	...	...	,, ,,	130 25½	,, ,,	130 18	3	,, ,,	130 4 – 130 27	Small; images poor.
k_2	9·20 35	012	...	111 8	36 10½	111 24½	36 15	1	110 33 – 112 30	... ...	Minute; image fair.
k_1	1·20·25	$1\bar{2}3$	...	,, ,,	49 15	,, ,,	49 30½	4	,, ,,	49 22 – 50 0	,, images poor.
k	$\bar{1}1·20·15$	$1\bar{1}1$	...	,, ,,	70 25	,, ,,	70 30½	14	,, ,,	69 55 – 71 10	Small; images fair.
z	$\bar{2}1·20·5$	$32\bar{1}$	...	,, ,,	98 33	,, ,,	98 10	10	,, ,,	97 27 – 98 50	,, ,,
z_2	$\bar{1}3·10·0$	$74\bar{1}$	...	,, ,,	111 58	,, ,,	110 45	1	,, ,,	... ...	Minute; image poor.
z_1	$3\bar{1}·20·5$	$21\bar{0}$	...	,, ,,	123 16½	,, ,,	124 5	1	,, ,,	... ...	,, ,,

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V_1	343	...	...	115	4	78	54	114	55	78	59	1	...	...	,,	,,	
V	785	...	...	,,	,,	80	32	115	45	81	10	1	...	...	...	...	,,	,,	
U_1	687	...	...	117	23	69	44½	117	47	70	17	8	117 38–117 56	70 10–	70 29	,,	images poor.
U	984	...	...	,,	,,	89	33½	116	36	89	27½	2	116 25, 116 47	89 25,	89 30	,,	,,
T	332	...	...	118	8	81	9½	118	47	80	31	1	...	...	...	...	,,	image good.
G_1	147	...	...	123	48	43	57½	123	47*	44	20	1	123 13–124 41	...	...	,,	image poor.
G	123	...	...	,,	,,	50	56½	,,	,,	51	10	1	,, ,,	...	...	Small;	,,
W	111	...	...	,,	,,	70	10	,,	,,	70	11	12	,, ,,	69 51–	70 25	,,	images fair.
W_1	876	...	...	,,	,,	76	56½	,,	,,	77	14	1	,, ,,	...	...	Minute;	image poor.
Θ	321	...	...	,,	,,	95	9	,,	,,	94	53½	7	,, ,,	94 35–	95 14	Small;	images fair.
Φ	210	...	...	,,	,,	118	24½	,,	,,	118	19½	9	,, ,,	117 30 –	118 37	,,	,,
Ψ_1	29.24.27	...	111	128	48	70	3½	129	0	70	16½	4	128 58–129 4	70 11–	70 21	Small;	images fair.
Γ_1	520	...	...	131	4	121	19	131	55	119	23	1	... ...	...	...	Minute;	image poor.
κ	112	...	...	137	2	50	33	136	43½	50	30	2	136 32–136 57	50 29,	50 32	Small;	images good.
Ξ	323	...	...	,,	,,	65	38	,,	,,	65	41	2	,, ,,	65 40,	65 42	,,	,,
Σ	211	...	...	,,	,,	85	15	,,	,,	85	10	1	,, ,,	...	...	Minute;	image fair.
Γ	521	...	...	,,	,,	106	0	,,	,,	106	1	1	,, ,,	...	...	,,	,,
Υ	21.20.45	325	...	140	4	48	22½	139	34	48	18	1	... ...	...	...	,,	,,
ν	15.4.1	...	...	145	54½	119	22½	146	19	119	24	1	... ...	...	...	,,	,,
F	17.4.3	...	...	152	0½	109	57½	...		...		1	... ...	...	...	See Table III.	

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As has already been stated, the prism zone is considerably striated parallel to the edge of the zone, so much so that in some cases no reliable measurements are obtainable. A few crystals, however, do possess definite faces giving bright and distinct reflections: one of these is exhibited in fig. 2. From a consideration of the measurements on all the crystals we may be certain of the existence of the forms a (100), c (001), e (101), E ($\bar{1}$01); but in the remainder of the zone measurable images are rare, and it is doubtful what forms are represented. Certain parts of the zone give an almost unbroken band of light.

A glance at the table shows that there is considerable variation about the mean value even in the case of measurements on which most reliance may be placed. We have remarked above that this variation cannot be explained as entirely due to errors of adjustment or observation; it must, therefore, have a real existence, and is, moreover, in accordance with the observations of those who have studied the characters of crystals growing in a saturated solution [1].

For convenience of reference the letters employed by Penfield and Ford to denote the terminal forms have as far as possible been retained in this paper. A study of Table II will show what changes have been made. In this table the monoclinic symmetry and the orientation of these authors have been adopted. The distances are given from the face perpendicular to the edge of the prism zone, and the zero azimuth passes through m (110). The values of these coordinates given on the left-hand side have been computed directly from the calculated values in Table I; on the right-hand side they are taken from the paper of Penfield and Ford [2], the observed values being the means of all those given in the different tables [3]. The symbols on the left-hand side assigned to the forms have been derived by transformation, with some slight alteration in certain cases for the sake of the resulting simplification. Keeping the zone $[c, f, p, m, w]$ unchanged, and substituting for o (121) the indices (13·22·10) of Penfield and Ford, we arrive at the following equations of transformation from one system to the other:—

$$(\lambda\mu\nu) = (9l + 2m,\ 11m,\ l - m + 11n);$$
$$(lmn) = (11\lambda - 2\mu,\ 9\nu,\ -\lambda + \mu + 9\nu);$$

where lmn, $\lambda\mu\nu$ are the symbols of any form according as the symmetry

[1] Cf. H. A. Miers: 'On a New Method of Measuring Crystals, and its Application to the Measurement of the Octahedron Angle of Potash Alum and Ammonia Alum.' Report Brit. Assoc., 1894 (Oxford), pp. 654–5.

[2] Loc. cit., p. 243.

[3] Loc. cit., pp. 230 et seq.

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TABLE II.—Comparison with the observations of Prof. Penfield and Mr. Ford.

Constants: $a:b:c = 1{\cdot}6304:1:1{\cdot}1468$; $\beta = 90°\ 10'$ (calculated from Table I).
$a:b:c = 1{\cdot}6318:1:1{\cdot}1449$; $\beta = 90°\ 12\frac{1}{3}'$ (Penfield and Ford)[1].

Form.			Calculated from Table I.				Form.		Calculated Values.				Observed Means.				No.
	T_1	M	Azimuth.		Distance.				Azimuth.		Distance.		Azimuth.		Distance.		
			°	′	°	′			°	′	°	′	°	′	°	′	
m	110	110	0	0	31	31½	m	110	0	0	31	30½	0	0	31	29	34
μ	$\bar{1}7{\cdot}24{\cdot}3$	13·33·1	9	33½	13	59	μ	17·40·2	9	30	14	28½	9	58	14	22	2
								33·80·4	9	47½	14	24					
x_1	19·20·5	441	19	56½	32	4	e	441	19	35	33	5	20	21	32	10	1
								42·44·11	20	26	32	1					
t	$\bar{1}10$	7·11·2	24	9	23	17	t	13·20·4	23	38½	23	32½	23	48	23	14	10
q	141	17·44·8	32	42	15	42½	q	11·29·5	32	52	15	30½	32	44	15	37	10
ζ	$\bar{2}3{\cdot}24{\cdot}3$	20·33·10	37	6½	25	0	h	21·37·11	36	40	23	30½	36	40	23	19	1
ω	29·20·15	20·15·12	39	30	47	29	ω	20·15·12	40	26	47	8	40	16	47	12	1
o	121	13·22·10	47	11½	28	7	o	13·22·10	47	30½	28	18	47	4	28	5	40
n	343	11·14·10	52	15	38	38	n	11·14·10	52	12	38	17½	52	18½	38	41	8
p	111	111	54	46	46	52	p	111	54	48	46	54½	54	47	46	52	33
i	823	10·7·11	57	17	58	6	i	10·7·11	57	18	58	29	57	9	58	6	2
π	$\bar{3}1{\cdot}20{\cdot}\bar{2}5$	658	61	37½	55	58	π	22·18·27	60	5	56	31	59	46	56	10	1
f	112	112	70	29	61	37	f	112	70	29	61	40	70	21	61	36½	2
g	123	4·7·10	73	52	52	46	g_1	10·15·22	71	36	52	38	72	6	52	49	1
							g	4·7·10	74	7	52	22	73	53	52	46	1
y	$\bar{1}2\bar{1}$	5·22·14	75	56	30	21	y	296	76	38	30	54	76	26	30	27½	7
v	011	2·11·10	81	48½	38	23	v	2·11·10	81	48	38	43½	81	57	38	20½	4
k	$\bar{1}1{\cdot}20{\cdot}15$	$\bar{1}0{\cdot}37{\cdot}22$	107	37	28	30½	k	$\bar{1}0{\cdot}32{\cdot}21$	108	18	31	6	108	27	31	8	1
r	$\bar{1}21$	5·22·8	114	42½	18	30	r	$\bar{1}0{\cdot}44{\cdot}15$	114	54	18	10½	114	41	18	28	9
w	$11\bar{1}$	$\bar{1}11$	125	1	46	48	w	$\bar{1}11$	124	55	46	48½	125	11	46	46	7
u	$12\bar{1}$	$\bar{1}3{\cdot}22{\cdot}12$	126	55	30	59	u	$\bar{1}1{\cdot}18{\cdot}10$	127	32	31	28	127	17½	30	58½	10
K	29·20·$\bar{2}5$	30·22·27	128	32½	53	19½	j	756	129	11½	53	31	128	50	53	30	1
x	9·20·5	$\bar{1}1{\cdot}20{\cdot}6$	141	36½	23	13	x	$\bar{1}1{\cdot}20{\cdot}6$	142	4	23	5	142	22½	22	53	5
							s	$\bar{1}1{\cdot}62{\cdot}6$	142	4	7	50					
b	010	2·11·1	141	24½	8	2	s_1	2·11·1	144	28	7	47	142	31½	8	4	29
							σ	2·10·1	144	28	8	33					
τ	$34\bar{1}$	$\bar{3}5{\cdot}44{\cdot}12$	153	45	28	30	τ	$\bar{3}1{\cdot}38{\cdot}11$	158	8	29	14	153	16	28	55	1
z	$2\bar{1}{\cdot}20{\cdot}5$	$\bar{1}5{\cdot}22{\cdot}1$	174	52	22	43½	z	$\bar{1}5{\cdot}22{\cdot}1$	174	84	22	46	174	22	22	39	3
ρ	49·20·5	$\bar{1}7{\cdot}9{\cdot}1$	176	8½	58	22	ρ	$\bar{4}4{\cdot}21{\cdot}2$	176	18	52	9	176	32	52	45	1

[1] Loc. cit., p. 227.

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is assumed to be triclinic or monoclinic. It will be noticed that there are two sets of the former corresponding to one of the latter, according to the sign given to the middle symbol.

To avoid the confusion due to the multiplicity of symbols, the following notation is adopted in this paper:—

(lmn) or (lmn) $\mathbf{T}_1$ are the indices of any form based on the first, the principal lattice;

(lmn) $\mathbf{T}_2$ are those based on the second lattice;

(lmn) $\mathbf{M}_2$ are those based on the third lattice;

($\lambda\mu\nu$) $\mathbf{M}$ are those based on the monoclinic symmetry and orientation of Penfield and Ford.

There are two points which call for remark in Table II: the distance of k and the azimuth of π differ appreciably from the values calculated from Table I. The discrepancy is probably due to the difficulty of correctly determining the position of a faint and indistinct image. The form k has been observed fourteen times by the author, and there can be little doubt of its true position; π has not been observed, but it falls very near a pole on the second lattice.

We may now return to the consideration of Table I. The positions of nearly all the forms recorded in that table are marked in fig. 3, which is a gnomonic projection on a plane perpendicular to the edge of the prism zone. The thick lines represent the zones of the principal lattice, and the thin lines those of the second lattice. The corresponding zones of the twin lattices are not drawn, to avoid complicating the diagram.

Almost without exception the terminal forms fall into zones passing through e (101)—it is in fact rare to find a zone without at least three forms in it, though not necessarily on any single crystal—and the angles between the forms in the same zone almost invariably obey the law of simple anharmonic ratios. After a few crystals had been measured in the manner described above, it was found that all the prominent faces lie in certain zones whose azimuths are approximately: 36½°, 46½°, 56°, 61½°, 75°, 82°, 68°–69°, 90°. Measurements were also made from the pole of intersection of the prism zone with that including the forms $[x, b, b', x']$; but no zonal relations could be found except those which naturally follow from the fact that the pole of reference is tautozonal with x and b, namely: $[\omega, p, P']$; $[x_1, o, y']$, etc. Now in the case of ordinary crystals, which are not twinned, the azimuths of pyramidal forms, when measured from a pole in the prism zone, representing an actual or a possible face, obey the law of simple anharmonic ratios. Such relations were accordingly looked for among the azimuths at e (101);

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but without success, until it was noticed that the first six do give simple ratios, but only if arranged in the following manner: $36\frac{1}{2}°$, $46\frac{1}{2}°$, $61\frac{1}{2}°$, 82°, 105°, 124°, the last two being the supplements of 75° and 56°; this is tantamount to assuming that the crystals have triclinic symmetry, and are pseudo-monoclinic owing to twinning about an axis parallel to

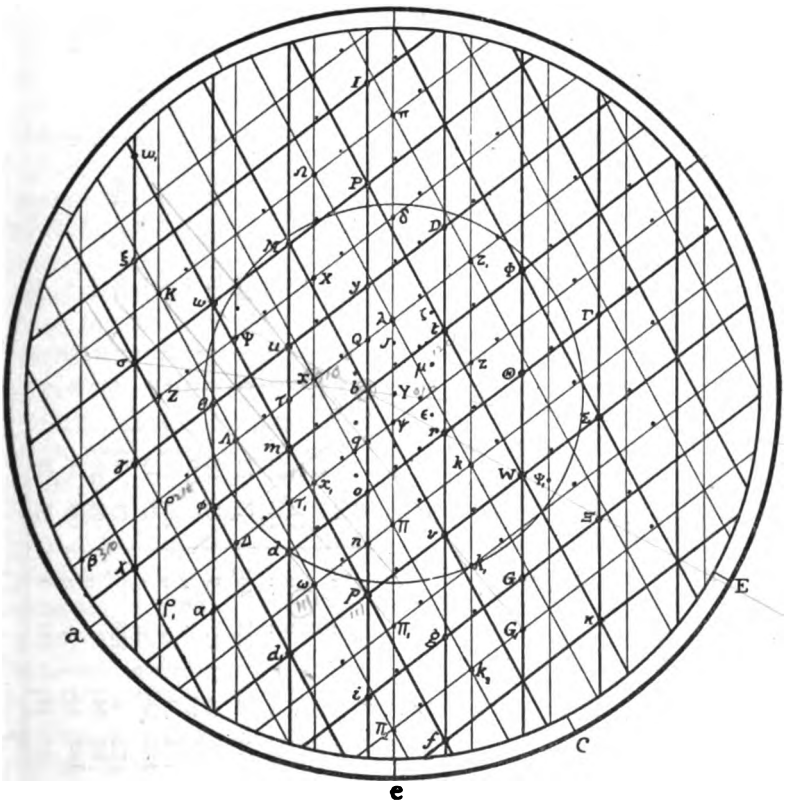

FIG. 3.—Gnomonic projection on a plane perpendicular to the edge of the prism zone (left-handed termination).

the edge of the prism zone. Further investigation revealed the existence of other zones, whose azimuths, 21°, 137°, 146°, also fall in with this arrangement.

The next step was to investigate the existence of cross-zonal relations, and accordingly measurements were made from the pole of intersection of the prism zone with the zone containing the forms $[m, b, t]$, at which a face, a (100), was frequently observed. Here again certain zones were

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TABLE III.—Measurements from *a* (100).

Form.		Calculated Values.				Observed Means.				Edges.	Limits of Observations.							
		Azimuth.		Distance.		Azimuth.		Distance.			Azimuth.				Distance.			
		°	′	°	′	°	′	°	′		°	′	°	′	°	′	°	′
e	101	0	0	52	18½	...		...		...	...		...		...		...	
p	111	53	1½	58	50	53	1	58	56½	14	52	28 –	53	20	58	43 –	59	22
v	011	,,	,,	78	52	,,	,,	78	48	3	,,	,,	,,		78	42 –	78	56
W	$\bar{1}11$	,,	,,	101	55	,,	,,	101	49	3	,,	,,	,,		101	48 –	101	50
F	$\bar{1}7.4.3$	61	42½	149	56½	61	54	150	37	1	...		...		...		...	
d	321	72	4½	48	19	72	4	48	23	3	71	32 –	72	26	48	9 –	48	30
o	121	,,	,,	67	58½	,,	,,	68	2½	14	,,	,,	,,		67	51 –	68	15
r	$\bar{1}21$	,,	,,	94	38½	,,	,,	94	38	6	,,	,,	,,		94	35 –	94	39
q	141	83	47	75	32½	83	41	75	36½	16	83	10 –	83	59	75	26 –	75	50
μ	$\bar{1}7.24.3$	89	54½	103	59	90	0	104	20½	7	89	55 –	90	7	104	12 –	104	34
φ	210	96	2	42	3	95	54½	42	1½	6	95	0 –	96	18	41	48 –	42	10
m	110	,,	,,	59	0	,,	,,	59	2½	22	,,	,,	,,		58	34 –	59	25
b	010	,,	,,	84	41	,,	,,	84	40½	18	,,	,,	,,		84	25 –	84	50
t	$\bar{1}10$	,,	,,	112	31½	,,	,,	112	29	8	,,	,,	,,		112	14 –	112	48
Φ	$\bar{2}10$	,,	,,	132	41½	,,	,,	132	32	3	,,	,,	,,		132	29 –	132	45
x	9.20.5	107	46	74	48½	107	45½	74	54	9	107	37 –	107	57	74	30 –	75	7
θ	$32\bar{1}$	118	9	55	24	118	7	55	28	3	117	45 –	118	24	55	20 –	55	30
u	$12\bar{1}$	,,	,,	76	29½	,,	,,	76	29½	12	,,	,,	,,		76	12 –	76	40
y	$\bar{1}2\bar{1}$	,,	,,	101	51½	,,	,,	101	51½	7	,,	,,	,,		101	42 –	101	59
D	$32\bar{1}$	,,	,,	123	25½	,,	,,	123	16	2	,,	,,	,,		123	11 –	123	21
w	$11\bar{1}$	133	57½	72	0	133	57½	71	49½	14	133	49 –	134	12	71	9 –	72	6
M	$01\bar{1}$	,,	,,	92	26½	,,	,,	92	25½	7	,,	,,	,,		92	6 –	92	45
P	$\bar{1}1\bar{1}$	,,	,,	112	18½	,,	,,	112	14	3	,,	,,	,,		112	4 –	112	21
w_1	$11\bar{2}$	151	15	81	49½	151	5	81	29	1	...		...		...		...	

The faces *F* and w_1 were observed only on a skeletal crystal, and owing to the peculiar shape of the crystal no measurements could be made of these faces from *e* (101).

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encountered which obey the same law, but only if arranged in the following manner: 53°, 72°, 84°, 96°, 118°, 134°. Measurements from this pole are given in Table III (p. 138), but only those of the more prominent forms made on fourteen crystals are included.

The zones of one individual very nearly coincide with those of the twin individual. For instance, the face q (141) of one lies very nearly in the zone $[m, b, t]$ of the other; in fact, on many crystals the agreement is so close that the slight difference may be due to error of adjustment; but, as a reference to the table will show, there is on the whole a small difference in the azimuths, amounting in the mean values to 24′.

Measurements were further taken from the intersection of the prism zone with the prominent zone containing the forms $[f, p, m, w]$; this pole is c (001) whichever class of symmetry be chosen, and frequently represents an actual face. Here again the azimuths satisfy the law of simple anharmonic ratios, but only if arranged in the following manner: 58½°, 70°, 77°, 98°, 111½°. Measurements from this pole are given in Table IV (p. 140), but only those of the more prominent forms made on thirteen crystals are included.

The concordance between the calculated and the mean observed values of the coordinates of the faces passing through the nodes of the principal lattice is so close that we can scarcely regard the agreement as accidental, and we must conclude that this lattice has a real existence in calaverite.

There are many forms which clearly from the complexity of their indices do not harmonize with the principal lattice: the most prominent of these are x (9·20·5̄), ω (29·20·15), k (1̄1·20·15), z (2̄1·20·5), Π (9·20·15), Λ (29·20·5̄), Ψ (19·20·1̄5), ρ (49·20·5̄). The indices, though complex, indicate that the faces are in harmony with a second lattice. The symbols which they receive on this hypothesis are given in another column of Table I. The prism zone is common to the two lattices, and the zones at a (100) are very nearly, if not quite, coincident. The positions of the forms of this group vary considerably. x (9·20·5̄), which is the best developed form, on some crystals lies very nearly in the zone $[o, r]$, but on others it lies an appreciable distance away. Again, the azimuth of the zone $[x, x_1, \omega]$ usually exceeds that of the zone $[k, z]$, but on some crystals it is distinctly less.

There still remain the common forms Y (5̄·24·3), μ (1̄7·24·3) and the rarer forms J (1̄1·24·3), Ψ_1 (2̄9·24·27), ζ (2̄3·24·3), ϵ (1̄1·24·9), which do not harmonize with either of the above lattices, but do harmonize with a third, a monoclinic, lattice. Here again the prism zone is the same as before.

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TABLE IV.

Measurements from *c* (001).

Form.		Calculated Values.		Observed Means.		Edges.	Limits of Observations.	
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
		° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′
e	101	0 0	27 36	...	...	...	... ...	... ...
f	112	58 28½	33 54	58 28½	33 58	5	58 7 – 58 57	33 20 – 34 6
p	111	,, ,,	53 19	,, ,,	53 21	17	,, ,, ,,	53 7 – 53 36
m	110	,, ,,	89 55	,, ,,	89 58½	12	,, ,, ,,	89 45 – 90 19
w	11$\bar{1}$	,, ,,	126 34	,, ,,	126 33½	10	,, ,, ,,	126 13 – 126 46
o	121	70 6	69 43	70 5½	69 43½	14	69 55 – 70 20	69 25 – 70 1
u	12$\bar{1}$	,, ,,	114 14½	,, ,,	114 16	5	,, ,, ,,	114 10 – 114 20
x	9·20·5	71 23	104 7	71 27	104 15	3	71 17 – 71 40	104 12 – 104 19
q	141	76 42	81 33	76 48	81 27½	7	76 40 – 77 5	81 10 – 81 45
v	011	83 41	52 3½	83 40	52 14	3	83 25 – 83 59	52 11 – 52 17
b	010	,, ,,	94 59	,, ,,	95 0	6	,, ,, ,,	84 52 – 85 25
M	01$\bar{1}$	,, ,,	133 39	,, ,,	133 43	3	,, ,, ,,	133 40 – 133 45
r	$\bar{1}$21	98 0½	73 16	97 57	73 20	6	97 45 – 98 10	72 41 – 73 30
y	$\bar{1}$2$\bar{1}$	,, ,,	119 28	,, ,,	119 25½	3	,, ,, ,,	119 6 – 119 30
k	$\bar{1}\bar{1}$·20·15	99 25	62 58	99 38	63 3	4	99 10 – 100 0	62 9 – 63 38
W	$\bar{1}$11	111 24½	57 6	111 16½	57 15	2	111 7 – 111 30	57 15
t	$\bar{1}$10	,, ,,	99 22	,, ,,	99 20	5	,, ,, ,,	99 16 – 99 38

We are, therefore, driven to the remarkable conclusion that five distinct lattices may be traced in calaverite, which are incongruent but not independent. The prism zone is common to all. The faces [*x*, *b*, *Y*, *b′*, *x′*] which lie on the different lattices are tautozonal; a fact which does not immediately follow from the symbols assigned to forms *x* and *Y*, namely (9·20·5) and (5·24·3) respectively, but these have merely been selected because they are the simplest which accord with the observations. There seems, indeed, from direct observation with the goniometer, no doubt that the faces in question do lie in a zone, and further we have tan *Yx* = 3 tan *Yb*, because this equation is satisfied by their azimuthal angles; for tan 82° 6½′ = 3 tan 67° 25′, which agrees closely with the mean observed azimuth of *x*, namely, 67° 29½′. The zones of the different

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lattices passing through $a(100)$ apparently coincide. Such is not the case at c (001); nevertheless there is a relation, as is clear from a study of the first two indices of the various forms, e.g.:—z (21·20·5), k ($\bar{1}\bar{1}$·20·15), x (9·20·5), Ψ (19·20·$\bar{1}\bar{5}$), ω (29·20·15), etc., and μ ($\bar{1}\bar{7}$·24·8), J ($\bar{1}\bar{1}$·24·3), Y (5·24·8), etc.; there is a regular decrement in the first very simply related to the second symbol. This relation is very clearly shown on the gnomonic projection; for, in consequence, the linear distances of points lying on parallel lines are multiples of the same unit. These several relations involve other tautozonal relations connecting poles on different lattices, such as: $[\rho, m, b', \Lambda']$, $[w', \Psi_1, W, k]$, $[Y, m, \beta]$, etc., in all of which the law of simple anharmonic ratios is obeyed. Finally, the two individuals of the two pairs of triclinic lattices are connected by twinning about Y or, what comes to the same thing, the edge of the prism zone.

The question now arises, what explanation can be offered of the unique anomalies presented by calaverite? On the one hand, we have a morphological development of the faces which is completely in accord with monoclinic symmetry. This view of the symmetry is confirmed by the frequent occurrence of a face of the form Y, which invariably gives a single distinct image, and not one blurred or double, such as would be expected did it really belong to two or more separate individuals. The faces also occur in positions similar to those of their poles on the sphere of projection, and there are none of the markings or re-entrant angles (beyond those in the prism zone) which usually accompany twinning, however much concealed. Later on, when we proceed to consider twin crystals, we shall find that the planes of twinning except that of the fourth, a doubtful type, have simpler indices on the hypothesis of monoclinic symmetry.

Yet, on the other hand, how can we be satisfied with an interpretation which necessitates the assigning of such complex symbols to even the commonest and best developed forms? The fundamental constants possess no meaning beyond the concise representation of the lattice of the space-partitioning. The crystal faces pass through the nodes of such a lattice, and the commonest faces are those in which the nodes are most crowded. Faces of this kind have simple indices; faces with complex symbols are usually due to corrosion. Although corrosion frequently does produce bright plane faces having high indices, we can scarcely regard all the faces of these crystals to be the result of corrosion.

Owing to the opacity of the crystals no optical test is possible, and, even if it were, it would not be infallible, since we know that if a crystal

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be composed of several overlapping individuals the resulting optical phenomena are precisely those of the symmetry simulated. Etching tests are more searching, but were in this case without result. A plane ground approximately perpendicular to the edge of the prism zone was etched with nitric acid and with aqua regia; the former produced numerous fine markings roughly in the same direction, and the latter merely a ripple effect.

A comparison of calaverite with the other gold tellurides, sylvanite and krennerite, does not throw much light on the problem, except for the interesting fact that the principal zone [*e*, *p*, *o*, *q*, *b*] of calaverite is similar to one zone of sylvanite and two zones of krennerite.

TABLE V.

Calaverite. Distance from 101.		Sylvanite[1]. Distance from 101.		Krennerite[1]. Distance from 100.			
° ′		° ′		° ′		° ′	
323	32 14	323	31 38½	301	31 52	320	32 5½
$\bar{3}23$	31 24						
111	43 38½	111	42 45	201	43 0	110	43 15
$1\bar{1}1$	42 15						
121	62 55½	121	61 35	101	61 48	120	62 0½
$\bar{1}21$	60 36						
141	76 22	141	74 56	102	74 59½		
$\bar{1}41$	73 34						
010	91 30	010	90 0	001	90 0	010	90 0
$0\bar{1}0$	88 30						

The zone [*c p m*] also has a counterpart in sylvanite.

TABLE VI.

Calaverite.				Sylvanite[1].			
Azimuth.		Distance.		Azimuth.		Distance.	
° ′		° ′		° ′		° ′	
111	58 28½	53 19		111	58 32	52 44	
110	„ „	89 55		110	„ „	89 47	

It is owing to this similarity that constants so nearly equal to those of sylvanite are obtained from calaverite on the hypothesis of monoclinic symmetry, and with the orientation of Penfield and Ford. If, indeed, we imagine the zone [*c*, *p*, *m*] kept fixed, and the remaining zones moved in such a way that *b* is brought into coincidence with *Y*, we obtain very nearly the constants and angles of sylvanite.

[1] The values are taken from Dana's 'System of Mineralogy,' 6th edition, 1892.

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Calaverite differs from sylvanite and krennerite in displaying no cleavage, although it is extremely brittle. If calaverite be really isomorphous with sylvanite, as is suggested by certain characters—the similarity of certain angles and zones, and the twinning about a similar face (type 1)—we should expect from analogy with the felspars, that even if they belong to different systems of symmetry both would display similar cleavage; but this is not the case. The brittleness of calaverite indicates that there is a facility of parting which is not in the same direction at every point. If the crystals are composed of two or more individuals so intimately intermixed that the separation is not visible to our perceptions, and if each individual has a cleavage in corresponding but not parallel directions, the brittleness would be explained: and further, if the constituent individuals at particular points are sufficiently small, the fractured surfaces would not give distinct and definite reflections; the surfaces in fact give a blur of light.

In the present state of our knowledge we can do little more than conjecture what may be the actual arrangement of the ultimate parts in any particular mineral, although we are agreed that it must belong to one of 230 different classes. The case of calaverite is one of peculiar perplexity. Professor W. S. Myers[1] has found that the composition of krennerite from the Cripple Creek District is essentially the same as that of calaverite; but the former crystallizes in the orthorhombic system and presents no anomalies. Whatever meaning may be attached to the three or, including the corresponding twins, five lattices apparently existing in calaverite, it is obvious that if they coexisted at every or, indeed, any point of the crystal, heterogeneity would be the necessary consequence of their incongruence. The only hypothesis remaining appears to be the existence of a minute skeletal structure of some kind—an infinitesimal framework composed of material with an arrangement according to one lattice intercalated with material with an arrangement according to another lattice. Since the lattices, while not congruent with one another, have a zone in common, i.e. the rows parallel to its edge equidistant, or at least congruent, in parallel planes, and have other relations, discussed above (pp. 140–1), interaction at some of the boundaries separating the differently constituted sections would seem to be indicated. This hypothesis is in harmony with the suggestion made above as to the origin of the brittleness of crystals. The frequent occurrence of pits on the faces, and the existence of skeletal and hollow crystals, suggest breaks in continuity of the homogeneous arrangement.

[1] Amer. Journ. Sci., 1898, ser. 4, vol. v, p. 376.

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As the facts require the parts of the hypothetical structure to be referable to three or more distinct structures, calaverite would then be in no way similar to such a substance as leucite, which exhibits optical anomalies. The optical investigation of such a substance shows that there is a clear and definite separation between the individuals which build up the crystal; on calaverite the faces occur just as they would if the crystal were composed of a single homogeneous individual.

Such are a few of the speculations that arise, but an adequate explanation is not forthcoming. Perhaps similar zonal relations may be found to exist in other minerals, and increased knowledge may furnish a clue which will ultimately lead to the elucidation of the mysterious symmetry of a most remarkable mineral.

Twin Crystals.

Whatever may be the explanation of the remarkable symmetry presented by calaverite, the crystals are susceptible of twinning in the usual manner about certain faces. Three types of twinning have been established, and to these possibly a fourth may be added.

Type 1. *Plane of twinning*: e_1 (705) T_1, (101) **M**.

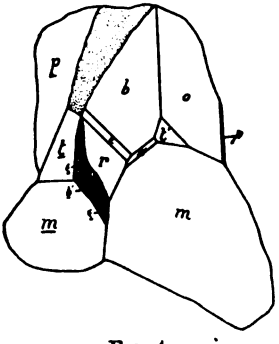

Fig. 4.
Twinned crystal (Type 1).

This, a very common type of twinning, has already been described by Penfield and Ford[1]. The twin striae mentioned by these authors were not noticed on any of the crystals measured, eleven in number. The plane of composition is usually either parallel or perpendicular to the plane of twinning. Fig. 4 shows the former mode and fig. 6 both; fig. 5 would probably have shown both had the crystal been unbroken. One large crystal possesses faces at the lower end which are in the positions required by this type of twinning, and the plane of composition is in this case at right angles to the edge of the prism zone. A line of demarcation runs round the prism zone, roughly at right angles to its edge.

In this type the faces of the form p (111) of the two individuals composing the twin are parallel, and the plane through the poles of these faces and the edge of the prism zone becomes one of symmetry. The crystals were measured in the usual manner, and one adjustment of the crystal is sufficient, since the direction of the edge of the prism zone

[1] Loc. cit., p. 237.

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is the same in the two individuals. The difference in the readings of the circle C, when each individual is in the position to be measured from a face of the form e (101) as pole of reference, gives at once the distance between the two positions of these faces. The mean of eight observed values, ranging from 14° 50′–15° 35′, is 15° 18′; the value calculated from the azimuth and distance of p (111), given in Table I, is 14° 56′, the half of which is 7° 28′. The calculated distance of e_1 (705) from e (101) is 7° 36½′. The plane of twinning might, of course, be in the prism zone distant a quarter of a revolution from e_1 (705), i. e. at a distance from e (101) of 82° 82′, the complement of 7° 28′. The nearest pole with simple indices is E_6 (201), the distance of which is 83° 1½′.

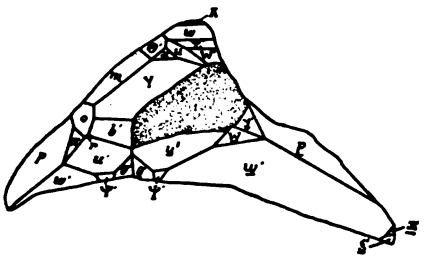

FIG. 5.

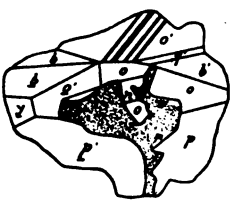

FIG. 6.

Twinned crystals (Type 1).

Some of the twins have a number of such minute faces on the boundary between the two individuals that considerable difficulty was experienced in determining to which of the two any particular face belonged. It may be remarked that, when the plane of composition is parallel or at right angles to the plane of twinning, the ends of the two individuals which compose the termination of the twin crystal are of opposite hands.

Type 2. *Plane of twinning*: p (111).

Penfield and Ford refer to this type, but the material at their disposal was not sufficiently good for the determination of the law of twinning. Fig. 7 represents an actual twin of this kind. The small portion to be noticed projecting from one individual is in the position required by the law of type 8. The other individual is remarkable for possessing both terminations. The angle in the prism zones towards the observer is re-entrant. The terminations of the crystals observed, four in number, have comparatively few faces.

These and other cross twins are easily measured on the three-circle

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goniometer. The prism edge of one individual is adjusted parallel to the axis of the circle *C*. The angle of crossing of the prism zones of the two individuals is at once determined, and measurements of the terminal faces of both may be made from the pole of intersection of the two zones. The individual, whose prism edge is in adjustment, may be measured in the usual way from the pole *e* (101). The second individual may then be adjusted and measured in a similar manner. The plane of twinning is now readily found. Measured from the pole of crossing, its distance is 90° and azimuth either half the acute angle or half the obtuse angle of crossing. Both will probably not give possible poles, but any doubt is removed by a consideration of the positions of the terminal forms of both individuals measured from the pole of crossing.

The plane of twinning does not seem to quite coincide with *p* (111). On the crystal figured the zone [*e*, *p*, *o*, *b*] is well developed on both individuals, and the two were found not to be in coincidence, as they should be. The mean value of the angle of crossing measured on the four crystals, ranging from 86° 33′–86° 54′, is 86° 41′; the calculated value is 86° 15′. The mean of four values of the distance of the pole of crossing from *e* (101), ranging from 82° 4′–82° 17′, is 82° 10′; the calculated value is 82° 32′.

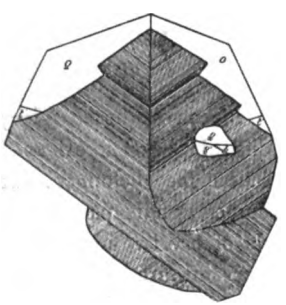

FIG. 7 (Type 2).

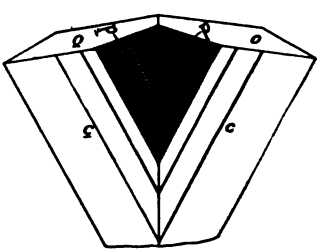

FIG. 8 (Type 3).

Twinned crystals.

Type 3. *Plane of twinning*: β (69·20·5) T_1, (310) T_2, (310) **M**.

In this type the prism zones cross at a much smaller angle (fig. 8). As in the previous type the terminations have comparatively few faces. Altogether six twins were observed, including that shown in fig. 7. They were measured in a similar manner to those of the preceding type. The mean of five values of the angle of crossing, ranging from 56° 29′–57° 38′, is 57° 5′; the calculated value is 56° 55′. No reliable measurements of the distance of the pole of crossing from *e* (101) were obtainable, owing to the insufficient development of the

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principal zone [*e*, *p*, *o*, *b*]. Four values were observed; 27° 43′, 28° 16′, 28° 47′, 29° 24′, the mean of which is 28° 37′; the calculated value is 27° 42′. The zones, therefore, cross very nearly in the pole *c* (001), the calculated distance of which from *e* (101) is 27° 36′. The faces of this form, belonging to the two individuals, seem to be coincident on the crystal figured.

One of the observed crystals is composed of three individuals, the middle one having an individual on each side in the positions required by twinning about the faces β and β'.

There are two crystals which call for special remark. At first sight they appear to be twins of type 3, and the angle of crossing is, indeed, the same; but on measuring one crystal, which is much better developed than the other, from the pole of crossing of the two prism zones it was found that the distances of the most prominent faces, evidently belonging to the form *o* (121), are not the same on the two individuals; on one the measurements were 69° 45′ and 69° 40′, and on the other 65° 19′ and 65° 31′. From further investigation it appeared that we have here a combination of the laws of types 1 and 3. Careful search was made for an intermediate individual, but no trace of such could be perceived on either crystal. The zone [*e*, *p*, *o*, *b*] is sufficiently well developed on one to furnish a fairly accurate setting for *e* (101), and the distance from this pole to the pole of crossing of the prism zones can be measured; it was found to be 41° 59′: the calculated value is the sum of 14° 56′ and 27° 42′, or 42° 38′. The calculated values of the distance of the faces of the form *o* (121) on the two individuals from the pole of crossing are 70° 6′ and 65° 17′, which are in fairly close agreement with the observed values given above.

Type 4. *Plane of twinning* (?): K_1 (19·20·35) T_1, (123) T_2.

The existence of this type requires further confirmation. Only one such crystal (fig. 9) has been observed, and that was encountered at the close of the investigation. Were it not for the occurrence of the crystals just described it would have been assumed to be a fortuitous conjunction of two distinct crystals. Each individual is capable of being measured with considerable accuracy, and each in turn was adjusted with its prism edge parallel to the axis of the circle *C*. The pole of crossing is not at the same distance from *e* (101) in the two cases; on the individual whose

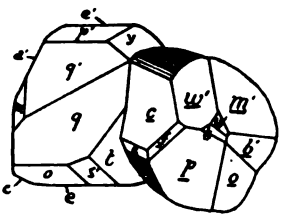

FIG. 9.
Twinned crystal (Type 4).

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prism edge is perpendicular to the plane of the paper in fig. 9, the distance measured is 25° 54′; on the other an accurate reading was not obtainable, but it is approximately 40° 35′. The difference between the two measurements is very suggestive, because it is very nearly that demanded by the law of type 1 as the angle between the two positions of *e* (101). We may, therefore, have again a combination of two laws, one belonging to type 1 and the other to a type to be determined. The observed angle of crossing is 60° 27′. The plane of twinning which satisfies the conditions best is K_1 (19·20·$\bar{35}$) T_1, (123) T_2, a form which has not yet been observed. The calculated value for the angle of crossing is 62° 49′, and that of the distances of the pole of crossing from *e* (101) on the two individuals is 41° 21′ and (less 14° 56′) 26° 25′. The agreement, therefore, between the calculated and observed values is not sufficiently close to prove the certain existence of this type of twinning.

Pseudomorphs.

The British Museum collection contains numerous altered crystals both on the matrix and isolated. They are usually prismatic with indications of terminal faces, but twins of types 2 and 3 have been noticed. Some consist apparently of pure gold, and others are merely altered on the surface. The colour is a rusty reddish-yellow or a pale buff-yellow. The alteration is evidently due to the oxidation of the telluride.

Chemical Composition.

Quantitative analyses were made by Mr. G. T. Prior on crystals carefully picked out from specimens from Raven Hill, and also on large isolated crystals without terminal faces, the exact localities of which are not stated on the labels.

The mineral was decomposed by aqua regia, and the small amount of silver chloride separated. In the filtrate the gold was precipitated by means of ferrous sulphate, and the tellurium by means of ammonium sulphite.

Results of analyses:—

	(1) Raven Hill crystals.	(2) Isolated crystals.
Weight of material used	0·5096 gram.	0·4196 gram.
„ Au	0·2123	0·1758
„ AgCl	0·0056	0·0034
„ Te	0·2949	0·2389

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	(1)	(2)	Calculated. $AuTe_2$
Au	41·66	41·90	44·03
Ag	0·77	0·79	....
Te	57·87	56·98	55·97
	100·30	99·62	100·00

The material contains, therefore, little silver. The numbers obtained in the analyses agree fairly well with the formula $AuTe_2$.

The following determinations of the specific gravity (i.e. the weight of 1 cc.) were made on isolated crystals, which were broken up into small fragments, but not crushed to powder, before being weighed:—

Weight of material used.	Specific gravity.
0·8131 gram.	9·163
0·7612	9·148
0·4259	9·153
	Mean value 9·155

The numbers here given agree closely with the determinations of Genth and Hillebrand; all are appreciably lower than the numbers given by Penfield[1], namely, 9·328 and 9·388.

Summary.

The following are the main points discussed in this paper:—

Judged merely from its morphological development, calaverite appears to crystallize in the monoclinic system, the axis of symmetry being parallel to the edge of the prism zone; but the indices which must be assigned to the faces on this hypothesis are exceedingly complex. The faces are, however, found to lie in zones, but these cannot be referred to a single space-lattice: in fact there appear to be in all five distinct lattices which are incongruent, but not independent; the relations between them are discussed above (pp. 140–1). Since the morphological development of the crystals cannot be referred to one lattice, calaverite cannot resemble in structure those transparent substances which display the so-called optical anomalies. The actual co-existence of two or more incongruent lattices would result in heterogeneity, and the only plausible hypothesis, by which we may explain the strange phenomena displayed by this mineral, seems to be that there is a close intermixture

[1] Loc. cit., p. 246.

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throughout the structure of arrangements corresponding to different lattices.

Four types of twin crystals are described, of which the fourth depends on a single crystal, and requires confirmation. In the case of two remarkable twins one individual may be derived from the other by means of successive half-turns about the twin axes of types 1 and 2; no trace of an intermediate individual is discernible. The crystal representing type 4 may be another instance of this double twinning.

The crystals contain little silver, and in chemical composition approximate to the formula $AuTe_2$.

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Sulpharsenites of Lead from the Binnenthal[1].

Part III.—Baumhauerite, a new mineral; and Dufrenoysite.

By R. H. Solly, M.A.
With an analysis by H. Jackson, M.A.

[Read November 12, 1901.]

Baumhauerite[2], $4PbS.3As_2S_3$.

FOR this new mineral I propose the name baumhauerite in honour of Dr. H. Baumhauer, Professor of Mineralogy in the University of Freiburg, Switzerland, who has done so much to elucidate this complicated group of sulpharsenites of lead.

Crystallography.

System: Oblique. $a : b : c = 1{\cdot}186817 : 1 : 0{\cdot}947163$; $\beta = 82°42\frac{3}{4}'$.

These elements are calculated from the angles $100 : 101 = 50°27'$, $101 : 001 = 32°15\frac{3}{4}'$ and $010 : 11\bar{1} = 50°33'$ measured on crystal No. I.

The crystals closely resemble dufrenoysite and jordanite in appearance. They may be distinguished from dufrenoysite by the marked oblique development of the zone [100,001], and from jordanite by the absence of twin striations and by the colour of the streak. The edges in the pyramid zone and between planes in the zone [100,010] are more or less rounded. The orthopinacoid (100), which is the direction of cleavage, is always largely developed and has a brilliant lustre; it is sometimes finely striated parallel to the axis of symmetry, and sometimes shows unsymmetrical markings. The best developed zone on the crystals is [100,001]. The prism zone [100,010] is sometimes deeply furrowed as in rathite and dufrenoysite. Sometimes similar planes on opposite sides of (010) give different angles; this may possibly be due to twinning about a plane making a small angle with (100),

[1] Part I.—General Description and Chemical Analyses, with a Crystallographic account of Jordanite. This Magazine, 1900, vol. xii, pp. 282–97. Part II.—Rathite. This Magazine, 1901, vol. xiii, pp. 77–85. These two parts have been published together in Zeits. Kryst. Min., 1901, vol. xxxv, pp. 321–44.

[2] A preliminary notice of this new mineral was published in 'Nature,' Oct. 10, 1901, vol. lxiv, p. 577, but no name was then given to it.

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as has been observed on rathite and dufrenoysite. The pyramid planes are fairly numerous but small. Table I given below contains the list of ninety-five forms which have been observed on the crystals. The positions of most of these forms are indicated on the stereographic projection (fig. 1).

There are four habits to be distinguished:—

I. Characterized by the large development of (010) (fig. 2).

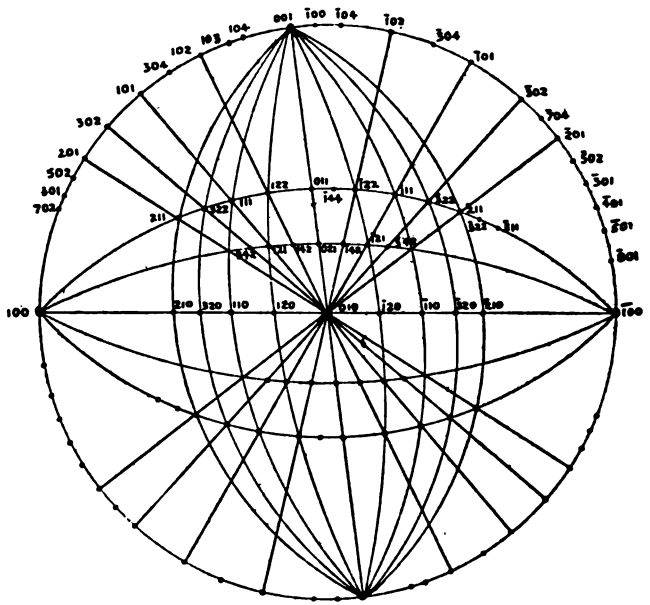

FIG. 1.—Stereographic projection of baumhauerite, showing most of the observed forms.

II. Plate-like crystals with (100) large, somewhat resembling jordanite in shape (fig. 3).

III. Rhombic prisms with small terminations, resembling habit I of dufrenoysite (p. 164).

IV. Simple rhombic-shaped crystals resembling Berendes' drawing of dufrenoysite.

The colour of baumhauerite is lead-grey to steel-grey, sometimes tarnished with iridescent colours. The lustre is metallic and brilliant. The streak chocolate colour. The mineral is opaque. There is a very perfect cleavage parallel to the orthopinacoid (100). Fracture conchoidal. Hardness 3. Specific gravity 5·330.

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Baumhauerite occurs, usually as isolated crystals, with the other sulpharsenites of lead in the white crystalline dolomite in the bed of the Lengenbach, Binnenthal; this is the only locality known for the mineral.

Two crystals have been examined by Prof. Baumhauer and his results are given below. My own observations have been made on thirteen crystals, two of which I obtained at Binn in 1898, and the others in August, 1901. There is little doubt that many museums[1] contain specimens of this new mineral under the name of dufrenoysite or jordanite.

TABLE I.—LIST OF FORMS OBSERVED ON BAUMHAUERITE.

Symbol.	Indices.	Symbol.	Indices.	Symbol.	Indices.	Symbol.	Indices.
a	100	$-\frac{5}{6}g$	508	$+\frac{2}{9}g$	205	$-2q$	121
b	010	$-\frac{1}{2}g$	102	$+\frac{1}{5}g$	308 *B.*	$-p$	111
c	001	$-\frac{2}{5}g$	205	$+\frac{1}{3}g$	103 *B.*	$+2q$	$12\bar{1}$
$-30h$	30.0.1	$-\frac{1}{3}g$	108	$+\frac{1}{4}g$	$10\bar{4}$	$+p$	$11\bar{1}$
$-\frac{25}{2}h$	25.0.2	$-\frac{1}{4}g$	104	$+\frac{2}{13}g$	$2.0.\bar{13}$	$+u$	$21\bar{1}$
$-\frac{13}{2}h$	13.0.2	$-\frac{1}{6}g$	106	$+\frac{1}{9}g$	$10\bar{9}$	$-4x$	342
$-5h$	501	$-\frac{1}{7}g$	107	$+\frac{1}{12}g$	$1.0.\bar{12}$	$-2x$	322
$-\frac{9}{2}h$	902	$-\frac{1}{9}g$	109			$+2x$	$32\bar{2}$
$-4h$	401	$+8h$	$80\bar{1}$	$4r$	140	$-4n$	142
$-\frac{7}{2}h$	702	$+\frac{11}{2}h$	11.0.2	$2r$	120	$-2n$	122
$-3h$	301	$+5h$	$50\bar{1}$	$\frac{4}{3}r$	340	$+4n$	$14\bar{2}$
$-\frac{13}{5}h$	13.0.5	$+4h$	$40\bar{1}$	r	110	$+2n$	$12\bar{2}$
$-\frac{5}{2}h$	502	$+3h$	$30\bar{1}$	$\frac{9}{8}s$	980	$-2y$	522
$-\frac{13}{6}h$	13.0.6	$+\frac{5}{2}h$	$50\bar{2}$	$\frac{33}{32}s$	320	$+2y$	$52\bar{2}$
$-2h$	201	$+\frac{11}{5}h$	11.0.5	$\frac{95}{96}s$	950	$+z$	$31\bar{1}$
$-\frac{13}{7}h$	13.0.7	$+2h$	$20\bar{1}$	$2s$	210	$-w$	411
$-\frac{3}{2}h$	302	$+\frac{13}{7}h$	13.0.7	$\frac{17}{8}s$	17.8.0	$-3W$	10.8.8
$-\frac{7}{5}h$	705	$+\frac{7}{4}h$	$70\bar{4}$	$\frac{65}{64}s$	520	$-3V$	16.8.8
$-\frac{4}{3}h$	403	$+\frac{5}{3}h$	503 *B.*	$\frac{33}{32}s$	880	$+4m$	$14\bar{4}$
$-\frac{7}{6}h$	706 *B.*	$+\frac{6}{5}h$	805 *B.*	$3s$	310	$-10T$	4.10.5
$-\frac{13}{12}h$	13.0.12	$+\frac{3}{2}h$	$30\bar{2}$	$\frac{10}{3}s$	10.8.0		
$-h$	101	$+h$	$10\bar{1}$	$\frac{11}{3}s$	11.8.0	k	011
$-\frac{5}{6}g$	506	$+\frac{3}{4}g$	$30\bar{4}$	$\frac{11}{2}s$	11.2.0	$2k$	021
$-\frac{4}{5}g$	405	$+\frac{2}{3}g$	203			$\frac{1}{2}l$	012
$-\frac{3}{4}g$	304	$+\frac{1}{2}g$	$10\bar{2}$				

B. refers to the planes observed only by Baumhauer.

[1] Measurement of a crystal which had been labelled as dufrenoysite in the British Museum gave angles agreeing with those of baumhauerite.—L. J. S.

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TABLE II.—CALCULATED AND MEASURED ANGLES OF BAUMHAUERITE.

	Calculated.	Measured (Solly).							Measured (Baumhauer).			
		Crystal I.	Crystal II (1).	Crystal II (2).	Crystal III.	Crystal IV (1).	Crystal IV (2).	Crystal V.	Crystal 1.	Crystal 2.		
										Fragment (1).	Fragment (2).	Fragment (3).
Zone [100,001]												
100 : 30.0.1	2°43′					2°40						
: 25.0.2	6 27					6 27						
: 18.0.2	12 6					12 0						
: 501	15 27				15°30′							
: 902	17 0½				17 0		16°50′					
: 401	18 54½						18 40	19° 0′				
: 702	21 15½		21°15′			21 16	21	21 14	21°20′*a*			
: 301	24 14		24 14	24°15′	24 14	24 14	24 12	24 12			24°16½′	24°17′
: 18.0.5	27 14	27°10′	27 14	27 15	27 14							
: 502	28 6	28 6				28 6	28 5	28 7	28 6	28°11½′	{ 27 56 / 28 0½ }	28
: 18.0.6	31 22	{ 31 6 / 31 55 }			31 20							
: 201	33 16½	33 16	33 16		33 16	33 17	33 16		33 20½	33 19½	{ 33 14½ / 33 15 }	33 15½
: 18.0.7	35 5		35 5									
: 302	40 24½		40 24	40 22	40 24	40 25			{ 40 22½*a* / 40 23½ }	40 27½	40 17	40 15*a*
: 705	42 9	41 21½										
: 403	43 22		43 22									
: 706	46 49								46 45½ *a*			
: 18.0.12	48 31½		48 30			48 32						
: 101	50 27	50 27	50 27	50 27	50 27	50 27	50 26		{ 50 27 / 50 27 }	50 27½	50 25	50 23*b*
: 506	54 39	54 40			54 42							
: 405	55 32				55 30							

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: 304	56 55½	56 55½			56 55						59 14½ *b*	
: 508	60 34½	60 35			60 34							
: 102	64 30½	64 30			64 30	64 30	64 50		64 35 64 35	64 27½	64 29½ 64 32	64 29 64 30½
: 205	67 53	67 50									67 17	
: 103	70 10½				70 10	70 12			70 28			
: 104	73 10½	73 9			73 10½				73 22½	73 9½ *a*	73 5	73 12 *a*
: 106	76 16½	76 16			76 16	76 25					75 46 *b*	
: 107	77 10				77 12							
: 109	78 23½				78 23						79 27 *b*	
: 001	82 42¾	82 43			82 43		82 45		83 6½ *b*		82 40	82 32½ *b* 82 42
100 : 80$\bar{1}$	10 23			10 10		10 24						
:11.0.2	15 5							15 0				
: 50$\bar{1}$	16 34		16 34		16 34							
: 40$\bar{1}$	20 34½			20 33		20 34		20 34				
: 30$\bar{1}$	26 58	26 58	26 57	26 50	26 58	26 58	26 51	27 0	27 0 26 52½		27 4	26 59½
: 50$\bar{2}$	31 44	31 44	31 44½	31 45	31 44	31 44	31 50	31 45	31 38 31 44½	31 44	31 54	31 48½
:11.0.5	35 23½		35 24									
: 20$\bar{1}$	38 16	38 16	38 15½	38 12	38 16	38 16	38 14		38 21½ 38 29	38 2½	38 12½	
:13.0.7	39 5		39 8									
: 70$\bar{4}$	42 27	42 26½	42 27	42 30	42 27	42 27			42 25 42 33		42 31½	42 29½
: 50$\bar{3}$	44 0								44 3½			
: 80$\bar{5}$	45 19½								45 16			
: 30$\bar{2}$	47 25	47 25	47 25			47 25	47 20		47 22½ 47 27½		47 24	47 25
: 10$\bar{1}$	60 19	60 19	60 19		60 19	60 19	60 20		60 13½ 60 31½		60 20	60 24½ 60 25
: 30$\bar{4}$	68 25				68 23	68 25						
: 20$\bar{3}$	71 21½					71 21			71 8			
: 10$\bar{2}$	77 32			77 30	77 34	77 32	77 31		77 31½ 77 32		77 38 *a* 77 34	77 48½ *a*

a = only fairly good; *b* = bad.

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	Calculated.	Measured (Solly).							Measured (Baumhauer).			
		Crystal I.	Crystal II (1).	Crystal II (2).	Crystal III.	Crystal IV (1).	Crystal IV (2).	Crystal V.	Crystal 1.	Crystal 2. Fragment (1).	Crystal 2. Fragment (2).	Crystal 2. Fragment (3).
: 205	81°22′				81°30′							
Zone [100,001]												
100 : 308	82 22½								82°20′			
: 103	84 1										84°7½′ *b*	84°6′ *b*
: 104	87 20	87°29′	87°20′	87°18′	87 20	87°20′	87°18′		{ 87 12½ / 87 17½ }	87°18′		
: 2.0.$\bar{1}$3	90 8½	{ 89 24 / 90 40 }			{ 90 20 / 90 40 }	{ 90 15 / 90 30 }						
: 105	92 20	92 20					92 50		92 56¾			
: 1.0.$\bar{1}$2	95 12½	95 20			95 12		95 15					
: 001	97 17½	97 17			97 17	97 18						
Zone [100,010]												
100 : 11.2.0	18 51½			18 55								
: 11.3.0	20 18½			20 20								
: 10.3.0	22 9		22 9									
: 310	24 20½		24 20									
: 330	26 58½	27 0	26 58									
: 520	28 30		28 30						28 27	28 30	28 42	
: 17.3.0	32 34		32 30									
: 210	34 9½	34 9	34 10						34 5	34 4		
: 950	37 1	37 0	37 0									
: 320	42 8	42 7½	42 8	42 7				42 10	41 57	42 11	41 55	
: 980	50 20½			50 18								
: 110	53 37	53 37								53 24	53 24½	
: 340	61 4½	61 4										
: 120	69 46½	69 46½						69 46		69 46¾		
: 140	79 34	79 32										
: 010	90 0	90 0								{ 90 0½ / 90 18 }	89 55	

a = only fairly good; *b* = bad.

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TABLE II (*continued*).

CALCULATED AND MEASURED ANGLES OF BAUMHAUERITE.

	Calculated.	Measured (Solly.) I.	II (a)	IV.	V.
Zone [100,011].	° ′	° ′	° ′	° ′	° ′
100 : 16.3.8	19 39½			19 40	
: 411	25 14½		25 15	25 16	
: 10.3.8	29 18		29 20		
: 522	36 20		36 23		
: 322	49 32½	49 32	49 33		
: 111	59 8½	59 4	59 4	59 8	59
: 122	70 54½	70 54	70 55	70 56	
: 011	84 42	84 40	84 43	85 0	
100 : 31$\bar{1}$	85 1½	85 0			
: 52$\bar{2}$	40 26	40 20	40 30		
: 21$\bar{1}$	47 22½	47 20	47 22		
: 32$\bar{2}$	56 17½	56 17	56 17		
: 11$\bar{1}$	67 31	67 31	67 31	67 30	67 30
: 12$\bar{2}$	80 53	80 54	80 54	80 55	
: 14$\bar{4}$	88 4	88 2			
: 01$\bar{1}$	95 18				
Zone [100,021].					
100 : 342	61 15½	61 10			
: 121	68 55	68 50			
: 4.10.5	72 14	72 15			
: 142	77 27	77 27			
: 021	86 35	86 30			
100 : 12$\bar{1}$	75 6	75 5			
: 14$\bar{2}$	84 6½	84 10			
: 02$\bar{1}$	93 25				
Zone [010,001].					
010 : 021	28 1½	28 3			
: 011	46 47	46 49			
: 012	64 50½	64 50			
Zone [010,101].					
010 : 121	34 24	34 30			
: 111	53 51½	53 52			

	Calculated.	Meas. I.
Zone [010,10$\bar{1}$].	° ′	° ′
010 : 12$\bar{1}$	31 17	31 20
: 11$\bar{1}$	50 33	50 33
Zone [010,20$\bar{1}$].		
010 : 21$\bar{1}$	59 36½	59 38
Zone [010,302].		
010 : 342	39 9½	39 12
: 322	58 27	58 27
Zone [010,30$\bar{2}$].		
010 : 32$\bar{2}$	55 6½	55 7
Zone [010,102].		
010 : 142	30 19	30 19
: 122	49 28	49 29
Zone [010,10$\bar{2}$].		
010 : 14$\bar{2}$	28 23½	28 33
: 12$\bar{2}$	47 14	47 14
: 11$\bar{2}$	76 59	77 0
Zone [001,110].		
001 : 111	46 56	46 56
: 110	85 41	85 41
: 11$\bar{1}$	128 9½	128 9
Zone [001,320].		
001 : 322	50 56	50 55
: 320	84 36	84 35
: 32$\bar{2}$	121 55	121 55
Zone [001,210].		
001 : 210	83 58½	83 59
: 21$\bar{1}$	116 21½	116 20
Zone [001,120].		
001 : 122	43 47	43 47
: 121	61 28	61 25
: 120	87 29	87 29
: 12$\bar{1}$	124 31	124 30
: 12$\bar{2}$	132 42½	132 42

DESCRIPTION OF INDIVIDUAL CRYSTALS.

Crystal I (fig. 2). — A small highly modified crystal of habit I. The clinopinacoid (010) and the orthopinacoid (100) are large. There are fifty-four forms developed on this crystal, including numerous pyramid planes; a list with the measured angles is given in Table II.

In the orthodome zone [100,001] at about 90° from (100) there are a number of narrow planes in oscillatory combination, suggesting that the crystal may be repeatedly twinned on (100), but the rest of the zone shows no indication of twinning.

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Crystal II (fig. 3).—This is a fine crystal of habit II; it is highly modified and plate-like in form. It broke into pieces on removal from the matrix of dolomite, and part of it was used for the chemical analysis.

The (100) face is large; the planes in the zones [100,010], [100,011] and [100,001] are narrow but well defined and give excellent reflections. The planes in the zone [100,021] were pitted and rough, so only approximate measurements could be obtained. The crystal has a slight iridescent tarnish. Forty-six forms were determined, a list of which together with the measurements appears in Table II under crystal II (1) and (2).

Crystal III.—A small crystal belonging to habit II; it is much modified, with rounded pyramid and dome zones. Thirty-three forms were determined in the zone [100,001] and are recorded in Table II.

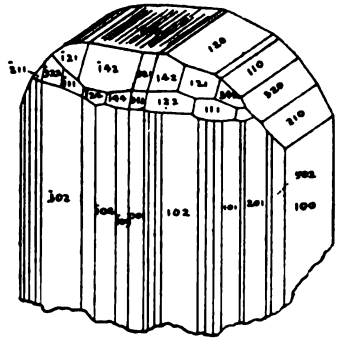

FIG. 2.—Baumhauerite (Habit I).

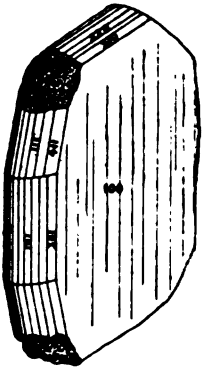

FIG. 3.—Baumhauerite (Habit II).

Crystal IV.—This crystal I found in 1898. I had four similar crystals, but one was used for analysis. They belong to habit II and resemble crystal II by the large development of the (100) face, but most of the planes in the dome and pyramid zone are much rounded. Thirty-three forms were determined in the zone [100,001].

Crystal V. This crystal closely resembles Berendes' figure of dufrenoysite. I obtained it in 1898, and it was not till I removed the crystal from the matrix of dolomite that its difference from dufrenoysite was perceived. The lustre of the upper faces resembles that of ground glass, but that portion of the crystal which rested on the matrix is bright. Fourteen forms were determined and are recorded in Table II.

Crystal VI (fig. 4). This is a very large crystal and measured $22 \times 9 \times 4$ mm. A small portion was broken off and used for analysis.

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Fig. 4 is an exact drawing of the crystal. The largely developed faces (100) consist of a number of thin laminae parallel to (100) of decreasing size; the edges are rounded in an unsymmetric manner conformable with the oblique symmetry of this mineral. The crystal is elongated along the axis of symmetry. I had three other very similar crystals, one of which was used for analysis. The following is a list of the forms that were determined on these crystals: (100), (702), (301), (502), (13·0·6), (201), (13·0·7), (302), (705), (403), (13·0·12), (101), (506), (102), (103), (104), (001), (30$\bar{1}$), (50$\bar{2}$), (11·0·5), (13·0·7), (70$\bar{4}$), (302), (10$\bar{1}$), (30$\bar{4}$), (10$\bar{2}$), (10$\bar{4}$), (10$\bar{9}$), (1·0·1$\bar{2}$), (520), (210), (320), (110), (52$\bar{2}$), (21$\bar{1}$), (32$\bar{2}$).

FIG. 4.—Baumhauerite.

CRYSTALS MEASURED BY PROF. BAUMHAUER.

In answer to my letter to Professor Baumhauer, proposing to give his name to this new mineral, he informed me that he had found two crystals of the same mineral in the Freiburg Museum. One of the crystals was detached, and the other was broken into three pieces in freeing it from the matrix. In sending me the results of his measurements, he asked that they might be included in the present paper. On reference to the above Table II, where these are given, it will be noticed that many of his angles are in close agreement with those obtained by myself: for example, the measured values for (100):(101) and (100):(10$\bar{2}$) are identical. In the prism zone [100,010] his measurements are, however, not in quite such close agreement and vary amongst themselves. The dislocation of the planes in this zone I have pointed out on p. 151.

The forms {706}, {503}, {805}, {303} and {103}, noted by Baumhauer, are not present on my crystals; on the other hand, he finds no definite pyramid planes such as are especially well developed on many of my crystals.

CHEMICAL ANALYSIS.

The following is Jackson's account of his analysis made on portions of crystals II, IV, and VI.

The mineral was examined and analysed as described in a former

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communication (this Magazine, 1900, vol. xii, p. 289). One quantitative analysis only was made, which gave the following results:—

Weight of mineral taken	=	·7785 gram.
„ $PbCl_2$	=	·5108 „
„ $BaSO_4$	=	1·382 „
„ As_2S_3	=	·3371 „

These give a percentage composition agreeing closely with the formula $4PbS.3As_2S_3$ [1]:—

	Found.	Calculated.
Pb	48·86	48·75
S	24·89	24·61
As	26·42	26·64
	99·67	100·00

The density of the crystals used had been determined as 5·329.

Of the previous analyses made on Binnenthal sulpharsenites of lead, the following one by Uhrlaub in 1855 (No. 8 in the table of analyses, Min. Mag., 1900, vol. xii, 287) appears to be referable to baumhauerite:—

Pb.	S.	As.	Ag.	Total.	Sp. gr.
47·58	24·66	25·74	0·94	98·92	5·405

Dufrenoysite, $2PbS.As_2S_3$.

Literature.

Damour, 1845, Ann. Chim. Phys., ser. 3, vol. xiv, p. 379. Analyses.
Von Waltershausen, 1855, Ann. Phys. Chem. (Poggendorff), vol. xciv, p. 115. Characters and Analyses.
Des Cloizeaux and Marignac, 1855, Ann. des Mines, ser. 5, vol. viii, p. 389. Crystallography.
Vom Rath, 1864, Ann. Phys. Chem. (Poggendorff), vol. cxxii, p. 373. Characters.
Berendes, 1864, Inaug.-dissert. Bonn. Analyses.
Baumhauer, 1894, Zeits. Kryst. Min., vol. xxiv, p. 85. Crystallography.
König, 1894, Zeits. Kryst. Min., vol. xxiv, p. 86. Analysis.
Baumhauer, 1897, Zeits. Kryst. Min., vol. xxviii, p. 551. Crystallography.
Guillemain, 1898, Inaug.-dissert. Breslau. Analyses.

The name dufrenoysite was given by Damour in 1845 after the French mineralogist P. A. Dufrénoy. From his analyses (see p. 167) of the massive material, he deduced the formula $2PbS.As_2S_3$, but, as pointed out by von Waltershausen in 1855, he made his crystallographic observations on the cubic mineral binnite (=tennantite).

[1] This formula, $4PbS.3As_2S_3$, has previously been assigned by Jackson to the new Binnenthal mineral liveingite, of which I have given a preliminary description in Proc. Cambridge Phil. Soc., 1901, vol. xi, p. 239. The analysis of liveingite agrees, however, more closely with the formula $5PbS.4As_2S_3$.

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Waltershausen, in 1855, figured a crystal which may be either dufrenoysite, baumhauerite or rathite; it cannot be sartorite on account of the large development of the (010) and (101) faces. The density he gives is 5·393, which agrees fairly well with that of baumhauerite (5·330), but the amount of lead (44·56 per cent.) found by Uhrlaub indicates a mineral lying between sartorite (Pb = 42·68) and baumhauerite (Pb = 48·75).

Des Cloizeaux and Marignac in 1855 described three crystals under the name of dufrenoysite. One of their crystals, of which a drawing is given [1], was of a large size, measuring 33 × 12 × 7 mm.; it had dull and rough faces, but with the hand-goniometer measurements were obtained, which agreed, Des Cloizeaux states, with the angles measured by Heusser on a sartorite crystal which he called binnite. Below is a comparison of these angles with vom Rath's calculated values for sartorite.

Des Cloizeaux (Dufrenoysite).	vom Rath (Sartorite).
$p : a^{\frac{1}{2}} = 31^{\circ}\,50'$	$001 : 011 = 31^{\circ}\,45'$
$p : a^{\frac{1}{3}} = 51\ \ 9$	$001 : 021 = 51\ \ 4$

Vom Rath, in his paper on dufrenoysite, considered this large crystal of Des Cloizeaux's, on account of its size and cleavage, to be dufrenoysite. If, however, importance is to be attached to the measurements of the dome zone, the crystal must be sartorite, as these dome planes are an invariable guide in distinguishing this species. The size is also not unusual for sartorite; I have some crystals nearly as large. The other two crystals described and figured (figs. 3, 3*a*, and 4) by Des Cloizeaux and Marignac are without doubt jordanite. Their fig. 3 represents a jordanite crystal twinned about (10$\bar{1}$) (= g^1 of Des Cl.); the plane (010) (= p of Des Cl.) shows characteristic twin lamination, which however is absent in the zone [010,10$\bar{1}$] (=[p, m] of Des Cl.). Des Cloizeaux lays much stress upon the existence of two cleavages p, good, and g^1, less perfect, at right angles to one another; I have pointed out (Min. Mag. xii, p. 294) similar cleavages, (010) and (10$\bar{1}$), on jordanite.

Vom Rath says in his paper that he knows of only four crystals of dufrenoysite. (1) A crystal measuring 20 × 8 mm., in the possession of Herr Wiser of Zurich, which was brought from the Binnenthal by Dr. Ch. Heusser and lent to vom Rath for measurement. (2) A very large crystal, belonging to Dr. Jordan, over 25 mm. across and weighing 18·5 grams. Vom Rath considered the low density (5·337)

[1] Fig. 2, plate vii of the memoir quoted above.

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of the crystal to be due to the cavities it contained. This crystal, he says, has a habit similar to Wiser's crystal. The faces are dull, rough, and pitted, but the horizontal striae on the (111) faces are distinct. Vom Rath does not seem to have been able to measure this crystal; I think it is most probably baumhauerite, not dufrenoysite. (3) Another crystal, about 25 mm. across, was goniometrically measured, and a portion of it was used for analysis. Sp. gr. = 5·569. The percentage of lead found by Berendes was 53·62 and 52·02, while 57·18 is required by the dufrenoysite formula. He considered the deficiency in the lead to be due to loss in analysis. (4) A smaller crystal, now in the Royal University Museum at Berlin; of this crystal he gives no details.

Baumhauer, in 1894, described some loose crystals with rounded terminal faces and with striated and channelled prisms; on one end of some of the crystals the (110) faces are developed. With the hand-goniometer the angle between 100:110 was measured as 42° to 43°. He found the density to be 5·553. The only measurements obtained on the reflecting goniometer were from small crystal fragments lining cavities in the large rough crystals. One of the large crystals was analysed by Professor König, who found that the chemical composition agreed closely with the theoretical one required for dufrenoysite.

Baumhauer in 1897 described a large crystal measuring 18 × 18 × 6 mm. It is deeply striated and furrowed parallel to the macrodiagonal, and on it he recorded eleven new forms.

Guillemain in 1898 gave the results of an analysis confirming the accepted formula of dufrenoysite.

It will be seen from the above summary of the literature that dufrenoysite is a comparatively rare mineral, and that the crystals are usually of a large size.

The axial ratios calculated by vom Rath from his measured angles $001:023 = 45°\,35'$ and $001:101 = 58°\,30'$ are $a:b:c = 0{\cdot}9381:1:1{\cdot}5309$. The present examination of eight crystals proves, however, that this mineral does not crystallize in the rhombic system but in the *oblique* system with the elements:—

$$a:b:c = 0{\cdot}650987:1:0{\cdot}612576;\ \beta = 90°\,33\tfrac{1}{2}'$$

as calculated from $100:101 = 47°\,2\tfrac{1}{4}'$, $101:001 = 43°\,31\tfrac{1}{4}'$ and $010:212 = 77°\,22'$ measured on crystal No. I (p. 167), which gives very sharp reflected images.

The plane (001) of vom Rath is the plane of symmetry (010), his (100) becomes (001), and (010) becomes (100). The parametral plane (111) remains unchanged.

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The crucial zone [100,001] is well developed on crystals I and IV, and the faces give very sharp reflections, but as a rule this zone is ill-defined and has rough faces. The pyramid planes in the + and − zones are seldom equally developed, and often only one of these zones is present on the crystals: the face (111) is usually smooth, while (11$\bar{1}$) is deeply striated parallel to the zone-axis [110].

The crystals are sometimes aggregated together in a manner resembling that of twin aggregations: these are described under crystal VI (p. 170).

The following table brings together for comparison the measurements obtained by vom Rath, Baumhauer and myself of the principal faces in the important zones.

	Calculated (Solly).	Rath 1st crystal.	Rath 2nd crystal	Baumhauer 1st crystal.	Baumhauer 2nd crystal.	Solly crystal I.	II.	III.	IV.	V.
	° ′	° ′	° ′	° ′		° ′	° ′	° ′	° ′	° ′
100 : 101	47 2½			46 56		47 2			47	
: 10$\bar{1}$	46 26½						46 26			46 27
101 : 001	43 31½	43 15		43 0	43°–44°	43 31				
$\bar{1}$01 : 00$\bar{1}$	42 59½						43 0			42 59
010 : 120	37 31½	37 15		37 24½	37°38′	37 31	37 30	37 31	37 30	37 32
: 230	45 41	45 35		45 38	45 26	45 41		45 41	45 40	45 43
: 110	56 56¼	56 46				57 0	56 58		56 56	
: 021	39 13	39 10	39 12	39 14	39 53	39 13	39 12	39 16		39 14
: 032	47 25	47 24	47 11½	47 22½	47 31	47 25	47 23	47 25		47 24
: 011	58 30½	58 30	58 29	58 33½	57 58½	58 30½	58 29	58 30		58 29
: 012	72 58½	72 58		72 57	72 25	72 57	72 58	73 0		72 50
: 232	56 5			56 12		56 4			56 3	
: $\bar{2}$32	56 20						56 25	56 23		56 21
: 111	65 51¼	65 54		65 51½		65 50			65 51	
: $\bar{1}$11	66 3½						66 3	66 4	66 4	66 3
: 212	77 22	77 29		77 19	77 18	77 22				
: $\bar{2}$12	77 29			77 32½			77 29	77 30		77 29

The planes in the zone [010,101] are usually small, smooth, or finely striated parallel to their intersections, and are associated with numerous minute pyramid planes; while the planes in the zone [010,10$\bar{1}$] are often largely developed, deeply striated or furrowed, with dull rough surfaces, and sometimes accompanied by planes in the zone [010,20$\bar{1}$]. The planes in the zone [100,010] are very numerous and some of them have high indices; this may be due to a tendency on the part of the crystal to repeated twinning about a plane inclined at a small angle to (010): such distortion in the position of the planes in this zone is often seen in a similar zone on rathite. The planes in the zone [010,001] are very numerous and usually exhibit fine striations parallel to their intersections

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with one another. The planes (210), (032), (012), (011) are large; while (410), (530), (052), (031) are medium in size; (110) is often well developed, but rough or pitted. The clinopinacoid (010) is sometimes large and smooth, but sometimes small and finely striated, parallel to the zone-axis [100]. The pinacoids (100), (001) are occasionally well developed, and the former shows distinct unsymmetric markings as is illustrated in fig. 6.

Table III contains the list of ninety-nine known forms, of which

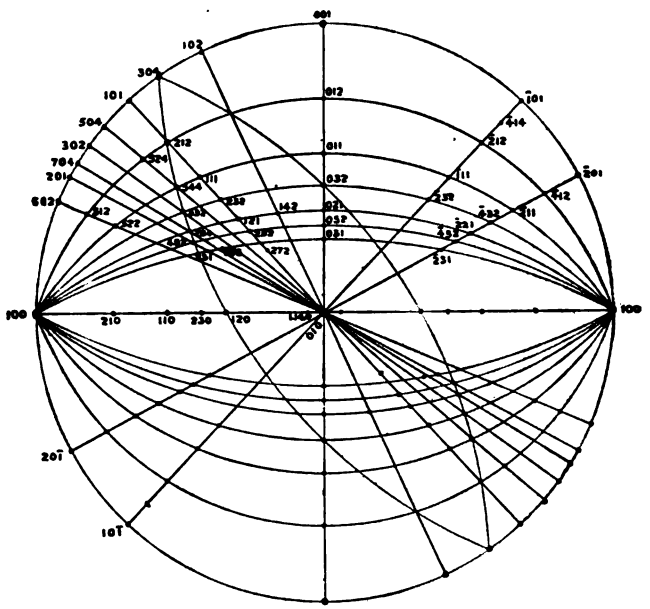

FIG. 5.—Stereographic projection of dufrenoysite, showing most of the observed forms.

seventeen had been recorded by vom Rath and eleven by Baumhauer. Baumhauer's planes (027) = (270) and (049) = (490) I have not found. The positions of many of the forms are indicated in the stereographic projection, fig. 5.

There are two distinct habits:—

Habit I. The crystals are elongated parallel to the zone-axis [100]; the plane (010), parallel to the direction of cleavage, is large and smooth.

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The zone [010,001] is largely developed, while the zone [100,010] is small; the pyramid zones are absent or ill-defined (fig. 8).

Habit II. The crystals are elongated along the axis of symmetry; (010) is small and finely striated parallel to its intersections with (001). In the zone [100,001] the planes (100), (101), (001), (10$\bar{1}$) are well developed.

TABLE III.—LIST OF FORMS OBSERVED ON DUFRENOYSITE.

Symbols.	Indices.	Rath.	Baumhauer.	Symbols.	Indices.	Rath.	Baumhauer.	Symbols.	Indices.	Rath.	Baumhauer.
a	100	b		$\frac{4}{3}s$	430			$\frac{1}{3}l$	013		
b	010	c		$\frac{5}{3}s$	530			$\frac{1}{4}l$	014		
c	001	a		$2s$	210			$\frac{1}{5}l$	015		
$-k$	101	m		$3s$	310			$\frac{1}{6}l$	016		
$+k$	10$\bar{1}$	m		$4s$	410			$\frac{1}{9}l$	019		
$-\frac{5}{2}h$	502			$6s$	610						
$-2h$	201			$14s$	14·1·0			$-\frac{1}{4}q$	272		
$+2h$	20$\bar{1}$							$-\frac{1}{3}q$	252		
$-\frac{7}{3}h$	704			$9k$	091			$-2q$	121		
$-\frac{3}{2}h$	302			$8k$	081			$-\frac{1}{2}q$	232		$\frac{1}{2}P$
$-\frac{4}{3}h$	504			$\frac{11}{2}k$	0.11.2			$+\frac{1}{2}q$	232		$\frac{1}{2}P$
$-2i$	102			$5k$	051			$-p$	111	o	
				$\frac{9}{2}k$	092			$+p$	11$\bar{1}$	o	
$14r$	1·14·0			$4k$	041	$\frac{1}{4}d$		$-2t$	212	$2o$	
$5r$	150			$\frac{7}{2}k$	072		207	$+2t$	21$\bar{2}$	$2o$	
$\frac{7}{2}r$	270		027	$3k$	031		103	$+\frac{3}{2}t$	343		
$3r$	130		013	$\frac{11}{4}k$	0.11.4			$-4t$	414		441
$\frac{5}{2}r$	250		025	$\frac{5}{2}k$	052		205	$+4t$	41$\bar{4}$		441
$\frac{4}{3}r$	490		049	$\frac{7}{3}k$	073			$-y$	522		
$2r$	120	f		$\frac{4}{3}k$	094			$-\frac{1}{3}y$	512		
$\frac{5}{3}r$	590			$\frac{11}{5}k$	0.11.5			$-3u$	231		
$\frac{7}{3}r$	470		047	$2k$	021	$\frac{1}{2}d$		$+3u$	23$\bar{1}$		
$\frac{8}{3}r$	350			$\frac{11}{6}k$	0.15.8			$-\frac{4}{3}u$	452		
$\frac{9}{2}r$	580			$\frac{7}{4}k$	074			$+\frac{4}{3}u$	45$\bar{2}$		
$\frac{5}{2}r$	230	f		$\frac{17}{10}k$	0.17.10			$+2u$	22$\bar{1}$		
$\frac{7}{2}r$	570			$\frac{9}{5}k$	053			$+\frac{3}{2}u$	43$\bar{2}$		
$\frac{4}{3}r$	340			$\frac{5}{3}k$	032	$\frac{2}{3}d$		$+u$	21$\bar{1}$		
$\frac{5}{3}r$	450			$\frac{4}{3}k$	043			$+\frac{1}{2}u$	41$\bar{2}$		
$\frac{8}{3}r$	560			$\frac{5}{4}k$	054			$-3z$	332		
$\frac{7}{2}r$	670			k	011	d		$-v$	544		
$11\frac{2}{3}r$	11·12·0			$\frac{8}{7}l$	056			$-\frac{1}{2}v$	524		
r	110	f		$\frac{3}{2}l$	034			$-8Z$	784		
$11\frac{2}{3}e$	12·11·0			$\frac{4}{3}l$	035			$-9Y$	593		
$\frac{1}{2}e$	760			$\frac{1}{2}l$	012	$2d$		$-4x$	142		

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TABLE IV.—CALCULATED ANGLES OF DUFRENOYSITE.

	° ′		° ′		° ′
Zone [100,001]		010 : 430	= 63 58½	010 : 013 = 78 27½	010 : 412 = 81 47½
100 : 502	= 23 7	: 530	= 68 40	: 014 = 81 17½	Zone [010,20$\bar{1}$]
: 201	= 28 6½	: 210	= 71 58	: 015 = 88 0	010 : 23$\bar{1}$ = 49 20
: 704	= 31 24	: 310	= 77 45½	: 016 = 84 10	: 45$\bar{2}$ = 54 24
: 302	= 35 30	: 410	= 80 45½	: 019 = 86 6	: 22$\bar{1}$ = 60 8½
: 504	= 40 36	: 610	= 83 48½	Zone [010,101]	: 43$\bar{2}$ = 66 45½
: 101	= 47 2½	: 14.1.0	= 87 20	010 : 272 = 82 31	: 21$\bar{1}$ = 74 1½
: 102	= 65 15½	Zone [010,001]		: 252 = 41 44½	: 41$\bar{2}$ = 81 51
: 001	= 90 33½	010 : 091	= 10 16½	: 121 = 48 7	Zone [010,502]
100 : 20$\bar{1}$	= 27 51½	: 081	= 11 32	: 232 = 56 5	010 : 522 = 76 28½
: 10$\bar{1}$	= 46 26½	: 0.11.2	= 16 31½	: 111 = 65 51½	: 512 = 83 8½
: 00$\bar{1}$	= 89 26½	: 051	= 18 4	: 212 = 77 22	Zone [100,012]
Zone [010,100]		: 092	= 19 56	: 414 = 83 36½	100 : 51$\bar{2}$ = 24 8½
010 : 1.14.0	= 6 15½	: 041	= 22 12	Zone [010,10$\bar{1}$]	: 524 = 41 58½
: 150	= 17 5	: 072	= 25 0	010 : 23$\bar{2}$ = 56 20	: 212 = 48 19
: 270	= 23 40½	: 031	= 28 33	: 343 = 59 24	: 012 = 90 32
: 180	= 27 7	: 0.11.4	= 30 41½	: 11$\bar{1}$ = 66 3½	: $\bar{2}$12 = 132 17
: 250	= 31 34	: 052	= 33 8½	: 21$\bar{2}$ = 77 29	: $\bar{4}$12 = 151 4
: 490	= 34 19	: 073	= 34 58½	: 41$\bar{4}$ = 83 40	Zone [100,011]
: 120	= 37 31½	: 094	= 35 57½	Zone [010,102]	100 : 52$\bar{2}$ = 26 35½
: 590	= 40 28½	: 0.11.5	= 36 34½	010 : 142 = 41 56½	: 544 = 45 9
: 470	= 41 16½	: 021	= 39 13	Zone [010,504]	: 111 = 51 33
: 350	= 42 40	: 0.15.8	= 41 2½	010 : 544 = 68 15½	: 011 = 90 28½
: 580	= 43 50	: 074	= 43 0½	: 524 = 78 48½	: $\bar{1}$11 = 129 2
: 230	= 45 41	: 0.17.10	= 43 50	Zone [010,302]	: 211 = 148 13
: 570	= 47 39	: 053	= 44 24	010 : 33$\bar{2}$ = 61 55	Zone [001,210]
: 340	= 49 2½	: 032	= 47 25	Zone [010,704]	001 : 21$\bar{2}$ = 44 58
: 450	= 50 52	: 043	= 50 45½	010 : 78$\bar{4}$ = 57 26½	: 210 = 90 31½
: 560	= 52 0	: 054	= 52 33½	Zone [010,201]	: 21$\bar{1}$ = 117 13
: 670	= 52 47	: 011	= 58 30½	010 : 23$\bar{1}$ = 49 6½	: 21$\bar{2}$ = 133 33½
: 11.12.0	= 54 37	: 056	= 62 57½	: 452 = 54 11½	Zone [001,110]
: 110	= 56 56½	: 084	= 65 19½	: 221 = 60 0½	001 : 11$\bar{1}$ = 48 34½
: 12.11.0	= 59 10½	: 035	= 69 49	: 432 = 66 35½	: 110 = 90 28
: 760	= 60 50	: 012	= 72 58	: 211 = 73 54	: 11$\bar{1}$ = 131 56½

The physical characters to be noted are the following:—

The colour is lead-grey to steel-grey, and the crystals are seldom tarnished. Streak chocolate colour. Opaque. There is a perfect cleavage parallel to the plane of symmetry (010). Hardness 3. Specific gravity 5·569 (vom Rath), 5·553 (Baumhauer), 5·52 (König), 5·50 (Solly).

Respecting the mode of occurrence, it may be noted that dufrenoysite is found only in isolated crystals in the dolomite or in cavities with similar crystals, unaccompanied by the other minerals commonly found in the dolomite. According to previous observers, only large crystals have been found, while those found since 1898 are small or moderately large. The only known locality is the bed of the Lengenbach, Binnenthal.

The published chemical analyses which have been made of dufrenoysite are collected together in the following table:—

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	Pb.	S.	As.	Ag.	Cu.	Fe.	Total.
$2PbS.As_2S_3$	57·18	22·10	20·72				100·00
König	57·42	22·55	20·89				100·86
Guillemain	57·38	21·94	21·01				100·33
„	56·73	21·18	20·04				97·95
Damour	56·61	22·30	20·87	0·17	0·22	0·32	100·49
„	55·40	22·49	20·69	0·21	0·30	0·44	99·53
Berendes	53·62	23·27	21·76	0·05		0·30	99·00
„	52·02	23·11	21·35				96·48

Description of Specimens.

The crystallographic observations have been made on eight loose crystals; three crystals on the matrix of dolomite were also examined. All of them have been found since 1898.

The largest specimen is an aggregation of a number of fine crystals resembling habit I; the largest crystal of the group measures about 15 mm. in length and the same in breadth. A small crystal which is described as No. VII was removed from this specimen.

Crystal I. (Fig. 6.)

This crystal, found in 1901, is remarkably brilliant; the planes are very smooth and give sharp reflections. The size is $18 \times 10 \times 5$ mm. It is elongated along the axis of symmetry, and (010) is small (habit II).

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,100].					
010 : 130	= 27° 7′	27° 5′	010 : 110	= 56°56½′	57° ′
: 120	= 37 31½	37 31	: 12.11.0	= 59 10½	59
: 590	= 40 28½	40 28½	: 760	= 60 50	61
: 470	= 41 16½	41 16	: 530	= 68 40	68 40
: 580	= 43 50	43 50	: 210	= 71 58	71 57
: 230	= 45 41	45 41	: 310	= 77 45½	77 45
: 570	= 47 39	47 39	: 410	= 80 45½	80 45
: 340	= 49 2½	49 2	: 610	= 83 48½	83 48
: 560	= 52 0	52 0	: 14.1.0	= 87 20	87 21
: 670	= 52 47	52 47	: 100	= 90 0	90 0
: 11.12.0	= 54 37	54 40			

The planes (100) and (210) are large. The plane (2$\bar{1}$0) has a deep furrow across the centre of the face, apparently parallel to the zone-axis [120]. This furrow has been observed on two other crystals; that it is intimately

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connected with the growth of the crystal is certain, but its crystallographic significance cannot be determined at present.

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,001]					
010 : 031	=28°33	28°33′	010 : 054	=52°33½′	52°32′
: 0.11.4	=30 41½	30 41	: 011	=58 30½	58 30½
: 052	=33 8½	33 8	: 056	=62 57½	63
: 094	=35 57½	35 57	: 034	=65 19½	65 18
: 021	=39 13	39 13	: 012	=72 58½	72 58
: 0.15.8	=41 2½	41	: 013	=78 27½	78 27
: 074	=43 0½	43	: 014	=81 17½	81 17
: 032	=47 25	47 25	: 016	=84 10	84 10
: 043	=50 45½	50 45	: 001	=90 0	90 0

The planes (021), (032), (011), (012) are well developed.

	Measured.		Measured.
Zone [100 : 001]			
100 : 101	=*47° 2¼	101 : 001	=*42° 31¼

The planes (100), (101), (001) are well developed. There are some very small planes between (100) and (101) which are probably (502), (201), (704), (802) and (504), but I could obtain no distinct images.

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,101]					
010 : 252	=41°44½′	41°44′	010 : 111	=65°51¼′	65°50′
: 121	=48 7	48 7	: 212	= —	*77 22
: 232	=56 5	56 4	: 101	=90 0	90 0

The plane (212) is very good, and the others are well defined. There are also other small pyramid planes. The planes (544), (524), (332), (784), (452), (522), and (512) were determined by measurement and zones.

	Calculated.	Measured.		Calculated.	Measured.
Zone [100,012]			Zone [100,011]		
100 : 512	=24° 3½′	24° ′	100 : 522	=26°35½′	27° ′
: 524	=41 53½	41 50	: 544	=45 9	45
: 212	=48 19	48 19	: 111	=51 33	51 35
: 012	=90 32	90 32	: 011	=90 28½	90 28
Zone [100,021]			Zone [100,052]		
100 : 784	=44 1	43	100 : 452	=44 20	44 15
: 121	=59 30½	59 30	: 252	=63 1	63 0
: 021	=90 21	90 21	: 052	=90 18½	90 19

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Zone [304,120] contains the planes (212), (544), (332), (784), (452) and (120).

Zone [010,504] „ „ (524), (544).

Zone [010,502] „ „ (522), (512).

Crystal II. (Fig. 7.)

This crystal I found in 1898; it belongs to habit II. The pyramids $+(11\bar{1})$ and $+(21\bar{2})$ are well developed, while in the negative octant the faces are small. The zone [010,100] is largely developed; [010,001] is medium in size. The plane (010) is small and finely striated parallel to the direction of the zone-axis [100]. The following planes are present:—(010), (001), (091), (052), (094), (0.11.5), (074), (0.17.10), (032), (011), (035), (012), (015), (019), (250), (120), (350), (230), (110), (272), (121), (232), (11$\bar{1}$), (21$\bar{2}$), (10$\bar{1}$), (142), (231), (593). The plane (272) is rough and lies in the zone [032,120].

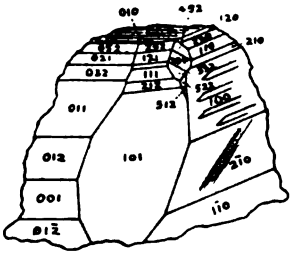

FIG. 6.

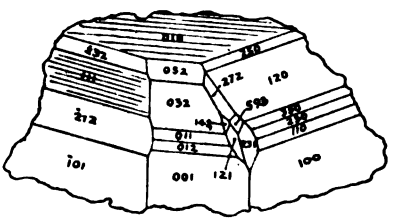

FIG. 7.

Dufrenoysite (Habit II).

	Calculated.	Measured.		Calculated.	Measured.
001 : $\bar{1}01$	$=42°59\frac{3}{4}'$	43° 0′	010 : $23\bar{2}$	$=56°20'$	56°18′
010 : 091	$=10\ 16\frac{1}{2}$	10 16	: $11\bar{1}$	$=66\ 3\frac{1}{2}$	66 3
: 0.11.5	$=36\ 34\frac{1}{2}$	36 32	: $21\bar{2}$	$=77\ 29$	77 29
: 0.17.10	$=43\ 50$	43 53	: $10\bar{1}$	$=90\ 0$	90
: 035	$=69\ 49$	69 50	: 142	$=41\ 57\frac{1}{2}$	41 57
: 015	$=83\ 0$	83 1	: 231	$=49\ 6\frac{1}{2}$	49 6
: 019	$=86\ 6$	86 5	: 593	$=45\ 13\frac{1}{2}$	45 14
: 250	$=81\ 34$	81 33			
: 350	$=42\ 40$	42 43			

Crystal III.

A small rounded crystal of habit II.

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The following planes are present:—(010), (120), (230), (450), (110), (011), (056), (034), (012), (23$\bar{2}$), (11$\bar{1}$), (21$\bar{2}$), (10$\bar{1}$).

	Calculated.	Measured.
010 : 450 =	50°52′	50°50′
: 11$\bar{1}$ =	66 3½	66 4
: 21$\bar{2}$ =	77 29	77 30

Crystal IV.

A small crystal of habit II with well developed (111) and (11$\bar{1}$), and small (101), (010); the other planes present are (100), (470), (230), (560), (110), (210), (410), (252), (121), (232), (011), (034), (012). The plane (111) is smooth, while (11$\bar{1}$) is striated parallel to the zone-axis [$\bar{1}$10].

	Calculated.	Measured.
100 : 101 =	47° 2¼′	47° 0′
111 : 110 =	41 53½	41 53
110 : 11$\bar{1}$ =	41 28½	41 29

Crystal V.

A small but highly modified crystal of habit II. The faces in the positive octant are well developed. The following planes are present:—(010), (100), (001), (150), (120), (230), (670), (110), (430), (210), (310), (410), (20$\bar{1}$), (10$\bar{1}$), (021), (0.15.8), (074), (0.17.10), (053), (032), (011), (034), (012), (23$\bar{1}$), (45$\bar{2}$), (22$\bar{1}$), (43$\bar{2}$), (21$\bar{1}$), (41$\bar{2}$), (23$\bar{2}$), (34$\bar{3}$), (11$\bar{1}$), (21$\bar{2}$), (41$\bar{4}$).

	Calculated.	Measured.		Calculated.	Measured.
010 : 150 =	17° 5′	17° 3′	010 : 45$\bar{2}$ =	54°24′	54°25′
: 430 =	63 58½	64 0	: 22$\bar{1}$ =	60 8½	60 7
: 053 =	44 24	44 25	: 43$\bar{2}$ =	66 45½	66 45
100 : 20$\bar{1}$ =	27 51½	27 51	: 21$\bar{1}$ =	74 1½	74 1
: 10$\bar{1}$ =	46 26¾	46 27	: 41$\bar{2}$ =	81 51	81 52
: 00$\bar{1}$ =	89 26½	89 26	: 34$\bar{3}$ =	59 24	59 26
010 : 23$\bar{1}$ =	49 20	49 21	: 41$\bar{4}$ =	83 40	83 41

Crystal VI. (Fig. 8.)

This crystal is typical of habit I. The face (010) is large, and the crystal is elongated along the zone-axis [100]. The zone [010,001] is largely developed and finely striated parallel to the zone-axis [100].

Attached to this crystal is a smaller one, which may be a twin growth resembling a growth observed on rathite (Solly, this Magazine, vol. xiii, p. 80). Two distinct images were observed on $0\bar{1}0$.

	Calculated.	Measured.
010 : $0\bar{1}0$ twinned about (1.14.0) =	11°42′	11°57′
,, ,, ,, (1.15.0) =	12 26	12 21

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The planes (001) of each crystal are nearly parallel to one another, but the planes (010), ($0\bar{1}0$) do not exactly lie in the zone [010,100]. If the crystal were twinned about (001) and (1.14.0) or (1.15.0), such an aggregation as is seen on this crystal VI would be formed. On crystals VII and VIII similar aggregations are found, but the angle between 010 : $0\bar{1}0$ is 2° 2′ and 1° 12′.

The following planes are present:—(010), (081), (092), (041), (072), (031), (052), (021), (0.15.8), (053), (032), (054), (011), (056), (034), (012), (013), (014), (001), (250), (120), (230), (252), (232), ($11\bar{1}$), ($21\bar{2}$).

Calculated.	Measured.	Calculated.	Measured.
010 : 081 = 11°32′	11°31′	010 : 072 = 25° 0′	25° ′
: 092 = 19 56½	19 55	$11\bar{1}$: $21\bar{2}$ = 11 25½	11 25
: 041 = 22 12	22 12		

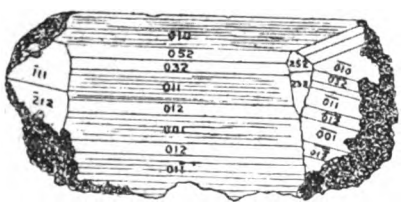

FIG. 8.—Dufrenoysite (Habit I).

Crystal VII.

This crystal of habit I was removed from the large specimen mentioned on page 167. The face (010) is large; the zone [010,10$\bar{1}$] is deeply striated; the zone [010,101] is small and rough. It exhibits an aggregation similar to crystal VI, as described above.

The following planes are present:—(010), (052), (021), (032), (011), (012), (001), largely developed; (091), (0.11.2), (051), (092), (041), (072), (031), (073), (074), (043), (054), (056), (034), small.

Calculated.	Measured.
010 : 0.11.2 = 16°31½′	16°31′
: 051 = 18 4	18 3
: 073 = 34 58½	34 59

Crystal VIII.

Similar to crystal VII. It exhibits an aggregation similar to VI, as described above.

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On Gibbsite from the Palni Hills in Southern India.

By H. Warth, D.Sc.

Late Deputy Superintendent, Geological Survey of India.

(Communicated by F. R. Mallet.)

[Read November 12, 1901.]

THE mineral described below was found by the present writer, in the year 1893, at Kodikanal on the Palni Hills, in the Madura District of the Madras Presidency. These hills, which rise at Kodikanal to a height of 7000 feet above the sea, form a range some thirty miles long in a WSW.–ENE. direction, with a breadth about half as great. They are composed of grey igneous rock, belonging to Mr. T. H. Holland's 'Charnockite' series, the slight foliation being in a direction coincident with that of the range, while the dip is at high angles. The mountains are at present mostly clothed with grass only, the soil being highly charged with peaty matter, and moderately fertile.

It is between this soil and the underlying rock that the mineral in question occurs, forming a loose bed about one foot thick. The bed was seen to be continuous throughout excavations which had been made over an area of several acres for planting purposes.

The mineral is perfectly amorphous, and takes the form of nodular plates up to half an inch in thickness. It becomes polished on rubbing with the fingers, and owing to its porosity it adheres readily to the tongue. The specific gravity is 2·42, and the colour nearly white with a cream or reddish tint.

On analysis of a pulverized sample, dried slightly above 100° C., I obtained the following results:—

	Found.	Calculated to 100.	Theory. ($Al_2O_3.3H_2O$).
H_2O . . .	33·74	34·95	34·58
Al_2O_3 . . .	62·80	65·05	65·42
Fe_2O_3 . . .	0·44	100·00	100·00
CaO . . .	0·20		
MgO . . .	0·03		
SiO_2 . . .	2·78		
TiO_2 . . .	0·04		
	100·03		

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The approximation to the theoretical composition of gibbsite ($Al_2O_3 . 3H_2O$) is therefore very close, and would be somewhat closer still if the ferric oxide were regarded as replacing an equivalent amount of alumina. Whatever part, however, it may have played originally, the ferric oxide now seems, in the main at least, to exist as an impurity, being chiefly concentrated in the minute fissures and cavities of the mineral. So far as I am aware, this is the first observed occurrence of gibbsite in India.

The mineral dissolves easily in hot, somewhat concentrated, sulphuric acid, and in hot sodium hydrate solution; less perfectly in hot hydrochloric acid. In the cold these solvents act very slowly. To determine the action of the reagents mentioned, I treated six portions of the pulverized mineral, each weighing one gram, with solvent, and after washing and igniting the residues, calculated the percentages of the original hydrous mineral corresponding to them :—

Solvent.	Temperature.	Duration of treatment.	Mineral left undissolved.
H_2SO_4 (sp. gr. 1·35)	boiling	5 minutes	3·8 per cent.
H_2SO_4 (sp. gr. 1·35)	cold	2 hours	57·7 ,,
HCl (sp. gr. 1·10)	boiling	5 minutes	20·7 ,,
HCl (sp. gr. 1·10)	cold	2 hours	83·7 ,,
NaOH (conc. sol.)	boiling	5 minutes	2·1 ,,
NaOH (conc. sol.)	cold	2 hours	86·9 ,,

The mineral does not decrepitate when heated in fragments. After ignition before the blowpipe, it scratched quartz and the specific gravity increased to 3·68. The pulverized mineral heated over the blowpipe became snow-white after cooling, notwithstanding the iron present[1].

In respect to origin, the mineral would seem to be a product of atmospheric decomposition of the underlying igneous rock. The composition of gibbsite is the same as that of the precipitate which forms when a current of carbon dioxide is passed through a solution of sodium aluminate, as in the technical preparation of pure alumina from bauxite. In the case of the Indian mineral, some alkaline aluminate may have been derived from the weathering rock, and acted on in dilute solution beneath the soil by carbon dioxide dissolved in percolating water, the alumina being thus precipitated as gibbsite.

[1] Cf. Chemical News, 1901, vol. lxxxiv, p. 305.

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The Cerargyrite Group (holohedral-cubic silver haloids).

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[Read February 4, 1902.]

Historical Introduction.—As given in modern text-books, the holohedral-cubic silver haloids occurring as minerals include the following species: the pure chloride, chlorargyrite, AgCl.; the pure bromide, bromargyrite, AgBr; the intermediate embolite, Ag(Cl,Br), containing chlorine and bromine in varying proportions; and iodobromite, containing all three halogens in a definite ratio corresponding to the formula 2AgCl.2AgBr.AgI.

The terms hornsilver (used by Gesner as far back as 1565) and cerargyrite (Beudant, 1832) are usually taken as referring only to the pure chloride. As regards their signification, however, they are equally applicable to all of the above species, and in lack of chemical analyses were certainly so applied in the past. Thus Breithaupt, after the discovery of the bromide and chloro-bromide of silver by Berthier in 1841 and 1842, remarks that many of the specimens of 'Hornerz' in the Werner Museum having a greenish colour probably contained bromine. The new bromide and chloro-bromide, together with the chloride of silver, were included by Breithaupt in the genus 'Cerargyrites.' In the present note we propose to so far revive this idea as to refer to all the holohedral-cubic silver haloids under the general name of cerargyrite.

To the chloro-bromide analysed by Plattner in 1849, and having the chemical composition expressed by the formula 3AgCl.2AgBr, Breithaupt gave the name embolite. That he regarded embolite as a definite species with this particular composition is evident from the fact that two other chloro-bromides, described by him in 1859 and showing ent proportions of the two halogens, he gave the distinct specific

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names megabromite (4AgCl.5AgBr) and microbromite (3AgCl.AgBr). Later analyses of chloro-bromides by Beck, Munro, Wood, and Field led to still other formulae, so that in 1886 it was pointed out by Welch that of fourteen published analyses, four corresponded more or less closely to 3AgCl.2AgBr, two to 5AgCl.2AgBr, and one to AgCl.AgBr, while seven called each for a separate formula. It has been recognized therefore that in these chloro-bromides the proportion of chloride and bromide may vary considerably. Embolite thus ceases to be a very definite species, since it may pass indefinitely, on the one hand into chlorargyrite, and on the other into bromargyrite.

It is one of the objects of the present paper to show that in the case of silver haloids containing all three halogens this history of embolite is repeating itself. Just as embolite was at first considered to have a fixed, definite chemical composition, so has the iodobromite, from Dernbach in Nassau, described by A. von Lasaulx in 1877[1], been regarded in the text-books as a mineral with the definite formula 2AgCl. 2AgBr.AgI.

Lasaulx claimed that iodobromite was the first mineral to be described as containing all three halogens. In 1869, however, F. A. Moesta[2] published an analysis of a chloro-bromide of silver from Chili showing a small percentage (1·73) of iodine in what would otherwise be described as an embolite. Previous to this, in 1853, Damour[3] had detected iodine in two specimens of olive-green silver bromide from Huelgoat, Brittany; and Dufrénoy in 1856 in his treatise mentions the isomorphous replacement of some of the chlorine by iodine in chlorargyrite from the same locality. Dufrénoy was thus led to consider the existence of a cubic silver iodide as probable, and even described[4] as such some bright yellow crystals on a specimen from Chañarcillo in the Muséum d'Histoire Naturelle in Paris; but as no chemical analysis was made of the crystals, it is probable that they contained all three halogens (see analysis of orange-yellow crystals of silver haloid from Chañarcillo on p. 179 below). More recently, in 1888, after the discovery of the silver ores of Broken Hill, A. Liversidge pointed out[5] that 'all the New

[1] Zeits. Kryst. Min., 1877, vol. i, pp. 506–7; Neues Jahrb. Min., 1878, pp. 619–23 (Abstract in this Magazine, vol. ii, p. 237).

[2] Ueber das Vorkommen der Chlor-, Brom- und Jodverbindungen des Silbers in der Natur (Ein Beitrag zur Kenntniss der geologischen und bergbaulichen Verhältnisse). Marburg, 1870, 47 pp., 4 plates. (Also as Habilit.-Schrift, Marburg, 1869.)

[3] Ann. des Mines, 1853, ser. 5, vol. iv, p. 332.

[4] Traité de Minéralogie, 2nd edition, 1856, vol. iii, pp. 452, 460.

[5] Journ. and Proc. Roy. Soc. N.S.W., 1888, vol. xxii, p. 365.

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South Wales silver chloride specimens' which he had examined 'contain iodine, some only traces, and others a fair percentage.'

In the present paper are given the results of qualitative and quantitative analyses made on very carefully selected material, showing that the chloride, bromide and iodide of silver may occur together in isomorphous mixtures in very varying proportions besides the particular one found by Lasaulx in iodobromite. Accordingly iodobromite, just as embolite, ceases to be a definite species. If the name were retained it might be applied to isomorphous mixtures of chloride, bromide and iodide of silver in which the three halogens are all present in fair amount; but since the name is a particularly misleading one, as suggesting that the mineral only contains iodide and bromide, we propose to refer to the varieties of the cerargyrite group which contain all three halogens as iodiferous embolites or briefly *iodembolites*.

Qualitative examination of Cerargyrites.—In order to test the present method of classification of the silver haloids a qualitative chemical examination was made of thirty-two specimens in the British Museum collection labelled chlorargyrite, bromargyrite, and embolite.

The method of analysis consisted in decomposing the mineral in the usual way by means of zinc and sulphuric acid, so that the silver was deposited and the halogens passed into solution as zinc salts. A portion of this solution was tested for iodine by the addition of one or two drops of a saturated solution of nitrous acid in sulphuric acid, and then for bromine (after the removal of the iodine dissolved in carbon bisulphide) by addition of chlorine water. Another portion of the solution was tested for chlorine by adding either potassium permanganate, or lead peroxide and acetic acid, boiling until all bromine and iodine were expelled, and treating with silver nitrate to precipitate the chlorine. As a confirmatory test a third portion of the original solution was treated with silver nitrate, and the resulting precipitate tested as to its solubility in ammonia.

The result of the qualitative examination given in the following table, showed that none of the specimens labelled bromargyrite consisted of *pure* bromide of silver, that many so-called chlorargyrites contained much bromine, and that many of the specimens referred to embolite contained iodine in varying amounts besides the chlorine and bromine.

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Number.	*Locality.*	*Colour.*	*Chlorine.*	*Bromine.*	*Iodine.*
Chlorargyrites:—					
1391	Johanngeorgenstadt	colourless	much	none	none
32977	S. America	,,	,,	,,	,,
36275	Copiapo, Chili	,,	,,	,,	,,
35839	Chili	greenish-yellow tinge	,,	,,	,,
54819	Taltal, Chili	greenish tinge	,,	,,	,,
Embolites:—					
34665	Dolcoath mine, Cornwall	greenish-grey	much	some	none
34293	,,	,,	,,	,,	,,
34295	,,	pale greenish-grey	,,	,,	,,
32133	Chañarcillo	,,	,,	little	,,
44464	,,	greenish-grey	,,	some	,,
34811	,,	,,	some	much	,,
A. G. 11	'Peru'	,,	much	some	,,
37086	Copiapo, Chili	,,	,,	little	,,
A. G. 8	S. America	,,	,,	some	,,
65398	Broken Hill	,,	,,	little	,,
65397	,,	pale greenish-grey	,,	,,	,,
37087	Plateros, Mexico	greenish-grey	very little	much	,,
Iodembolites:—					
83458	Broken Hill	pale greenish-grey	some	some	very little
76235	,,	,,	,,	,,	,,
71533	,,	,,	,,	,,	little
80678	,,	pale greenish-yellow	,,	,,	very little
64379	,,	,,	,,	,,	little
85484	,,	greenish-yellow	,,	,,	,,
64376	,,	,,	,,	little	much
84822	,,	,,	much	some	little
83825	,,	orange-yellow	some	,,	much
44459	Chañarcillo	greenish-yellow	,,	,,	some
35842	,,	,,	,,	little	,,
36280	,,	orange-yellow	,,	some	,,
53925	,,	,,	,,	little	,,
46189	,,	,,	,,	some	little
40661	Catorce, Mexico	pale greenish-yellow	,,	,,	some

IODEMBOLITES.

Four of the specimens which the qualitative examination had shown to contain all three halogens were selected for more detailed investigation and quantitative analysis. The following description of the physical characters applies mainly to the three first well-crystallized specimens (*A*, *B*, *C*).

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Physical Characters.—The crystals on all three specimens, although differing considerably in chemical composition, are very similar in general appearance. The faces are bright and smooth, but not perfectly plane, so that only approximate measurements can be obtained on the goniometer. The angles measured agree closely enough with cubic angles, and the only forms present are the cube $a\{100\}$ and octahedron $o\{111\}$. On the Broken Hill specimens a few of the crystals are twinned according to the spinel-law. The colour of the crystals of two specimens (*A* and *B*) is bright orange-yellow, that of specimen *C* is greenish-yellow; but this is soon altered to green on exposure to light. The crystals are translucent, and only small fragments allow of the passage of sufficient light for examination under the polarizing microscope. Small crystals which have not been distorted are optically isotropic, but when bent are feebly birefringent with undulose extinction. The mineral is very tough and sectile. The hardness is $2\frac{1}{2}$. Fragments are readily flattened when pressed with a knife-blade and leave no mark (streak) on paper. The fracture is uneven to sub-conchoidal, and no cleavage could be developed in the directions of the faces of the cube, octahedron or rhombic dodecahedron.

Method of Analysis.—For the analysis only crystallized material was taken, on which no iodyrite could be seen. Any calcite, oxide of iron and native silver were removed by digestion in dilute nitric acid; clayey material and some of the smaller garnets were removed by washing in a stream of water, after which the material was carefully picked out under the lens and examined under the microscope.

In all the analyses the mineral in small fragments was decomposed by means of zinc and sulphuric acid. The silver was collected, washed and dissolved in nitric acid, any insoluble residue (quartz or, in the case of the Broken Hill specimens, minute garnets) being separated at this stage and weighed. The total silver was then precipitated as chloride and weighed. The solution containing the halogens as zinc salts was transferred to a separator and treated with a few drops of a saturated solution of nitrous acid in sulphuric acid. The liberated iodine was dissolved in carbon bisulphide, and the solution collected on a moist filter, washed and titrated with sodium thiosulphate. The sodium thiosulphate solution was standardized by means of pure iodine dissolved in potassium iodide, which was treated in the separator with carbon bisulphide, collected on a filter, and washed in precisely the same way as the iodine solution in the analyses. For the determination of the chlorine and bromine, the indirect method was adopted of precipitating

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with silver nitrate, weighing the combined silver chloride and bromide, and then converting wholly into chloride by reducing with zinc and sulphuric acid, dissolving the silver in nitric acid and reprecipitating with hydrochloric acid.

The results thus obtained are given under I, but as a check there are also given under I (*a*) the results of the more indirect calculation of the percentages of the chlorine and bromine from the weights of the total silver and iodine, together with the weight of the mineral used in the analysis. In each case the two results show a fairly close agreement. The atomic weights used were Ag=108, Cl=35·5, Br=80, I=127.

A. Specimen (No. 36280) *from Chañarcillo, Chili.*

The matrix of this specimen is a crystalline limestone which in places is ferruginous, argillaceous, or quartzose, with patches of red hydrated oxide of iron. Embedded throughout are small particles of native silver. Cavities in the mass are lined with crystals of calcite, and on these rest the bright orange-yellow cubo-octahedra of iodembolite, the largest of which are about 7 mm. across. The same cavities also sometimes contain aggregates of small indistinct crystals of pale sulphur-yellow iodyrite, which in places rest upon the orange-yellow cubo-octahedra.

Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag	60·37	60·37
Cl	7·11	6·95
Br	22·35	22·29
I	10·39	10·39
	100·22	100·00
This corresponds to:—		
AgCl . . .	28·72	28·38
AgBr . . .	52·53	52·39
AgI . . .	19·23	19·23
	100·48	100·00

Weight of mineral used = 0·8645 (after deducting 0·0081 insoluble). I = 0·0868; AgCl corresponding to total silver = 0·6949; AgCl + AgBr after separation of iodine = 0·7025; AgCl equivalent to AgCl + AgBr = 0·5950 gram.

Approximate formula: 5AgCl.7AgBr.2AgI.

Specific gravity (weight of 1 cc. at 23° C.)=6·17.

B. Specimen (No. 83825) *from Broken Hill, New South Wales.*

This specimen consists of a large crumbly, but closely set mass of arborescent native silver, the branches of which are encrusted with

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bright but minute and indistinct crystals of silver[1]. This is abundantly encrusted with small bright cubo-octahedra of the orange-yellow iodembolite, with which are associated numerous minute reddish garnets, a few angular fragments of quartz sometimes with a bluish opalescence, and a yellow clayey material. Often the crystals of iodembolite are nothing more than hollow shells of material around the native silver, from which the mineral has no doubt been derived. These shells contain in their interior a loose granular aggregate of minute crystals, occasionally distinguishable under the microscope as cubo-octahedra, and, as far as can be seen, with the same characters as the enclosing shells and larger crystals, with which they are no doubt identical. Minute reddish garnets are sometimes completely embedded in the crystals of iodembolite.

This and the following specimens showed no iodyrite in association with the iodembolite, while on almost all other specimens of a similar character from Broken Hill it is present. Usually in these cases the pale yellow iodyrite rests on the darker yellow cubic mineral, though sometimes the reverse is the case.

Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag . . .	56·93	56·93
Cl . . .	1·96	1·70
Br . . .	32·22	32·60
I . . .	8·77	8·77
	99·88	100·00
This corresponds to:—		
AgCl . . .	7·93	7·16
AgBr . . .	75·78	76·61
AgI . . .	16·23	16·23
	99·89	100·00

Weight of mineral used = 0·9311 (after deducting 0·0116 insoluble). I = 0·0816; AgCl corresponding to total silver = 0·7043; AgCl + AgBr after separation of iodine = 0·7789; AgCl equivalent to AgCl + AgBr = 0·6120 gram.

Approximate formula: 5AgCl.40AgBr.7AgI.

Specific gravity (weight of 1 cc. at 18° C.) = 6·31.

[1] These crystals of silver are rarely suitable for goniometric measurement, but on one of them the forms *a* {100}, *d* {110}, and {10.3.0} were determined. The form {10.3.0} does not appear to have been previously recorded on native silver: measured to *a* (100), 16½° to 17°; calculated (100) : (10.3.0) = 16° 42′ (L. J. S.).

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C. Specimen (No. 84822) *from Broken Hill, New South Wales.*

This specimen consists almost wholly of a cellular aggregate of greenish-yellow cubo-octahedra of iodembolite. As in the specimen last described these crystals are often only hollow shells of material. The faces of the cube have a drusy or tesselated appearance, owing to the grouping of smaller crystals in parallel position. Brownish garnets occur abundantly embedded in the crystals of the iodembolite. Minute grains of garnet are sometimes aggregated into curious angular forms, of a flesh-pink colour, suggestive of pseudomorphs, or at first sight somewhat resembling crystals of marshite. Psilomelane and limonite are also present in small amount.

Result of analysis (G. T. P.) :—

	I.	I (*a*).
Ag . . .	67·28	67·28
Cl . . .	14·36	14·14
Br . . .	15·85	16·23
I	2·35	2·35
	99·84	100·00

This corresponds to :—

AgCl . .	58·04	57·17
AgBr . .	37·24	38·48
AgI . . .	4·35	4·35
	99·63	100·00

Weight of mineral used = 0·7409 (after deducting 0·0166 insoluble). I = 0·0174 ; AgCl corresponding to total silver = 0·6623 ; AgCl + AgBr after separation of iodine = 0·7059 ; AgCl equivalent to AgCl + AgBr = 0·6406 gram.

Approximate formula : 20AgCl.10AgBr.AgI.

Specific gravity (weight of 1 cc. at 23° C.) = 5·82.

D. Specimen (*No.* 83458) *from Broken Hill, New South Wales.*

This specimen represents what appears to be the commonest type of silver haloid from Broken Hill. It is a large cellular or coralloidal mass, evidently a pseudomorph after wiry native silver, as suggested also by the associations of specimen *B*. The surface of the branches and wires has a drusy aspect, but no definite crystalline form can be distinguished. The colour is pale greenish-grey. The material is tough and sectile. The hardness is 2½. Associated minerals, present in only very small amount, are psilomelane, limonite and small brown garnets.

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Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag . . .	66·91	66·91
Cl . . .	18·20	18·18
Br . . .	19·71	19·75
I	0·16	0·16
	99·98	100·00

This corresponds to:—

AgCl . .	53·86	53·28
AgBr . .	46·33	46·43
AgI . . .	0·29	0·29
	99·98	100·00

Weight of mineral used = 1·2565 (after deducting 0·0045 gram insoluble). I = 0·0020; AgCl corresponding to total silver = 1·1170; AgCl + AgBr after separating iodine = 1·2525 gram.

Approximate formula: 3AgCl.2AgBr.

Specific gravity (weight of 1 cc. at 17° C.) = 5·66.

Conclusions.

Collecting together for convenience of comparison the foregoing results, we have:—

	A.	*B.*	*C.*	*D.*
AgCl . . .	28·72	7·93	58·04	53·36
AgBr . . .	52·58	75·78	37·24	46·33
AgI . . .	19·23	16·23	4·35	0·29
Sp. gr. . . .	6·17	6·31	5·82	5·66

These analyses, together with those of other authors, show that the chloride, bromide and iodide of silver can form isomorphous mixtures in very varying proportions. In the case of the chloro-bromides where the limiting members of the series both crystallize only in the cubic (holohedral) system, there is no reason to doubt that isomorphous mixture may take place in any proportion whatever. With the chloro-bromo-iodides the case is different, since the pure iodide, as it occurs in nature and at temperatures below 146° C., is crystallographically distinct from the chloride and bromide. In the latter case it is conceivable that there may be a limit to the amount of iodide which can enter into isomorphous mixture with the chloride and bromide, and that when this limit is passed the excess of iodide will crystallize out as hexagonal iodyrite. In this connexion therefore it is of interest to recall the fact

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already mentioned that of the four specimens of iodembolite analysed, iodyrite occurs only in association with the one from Chañarcillo in which the largest percentage of iodine (10·39) was found: iodyrite also occurs in association with the 'iodobromite,' from Dernbach, which contains a still larger percentage of iodine (15·05).

In order if possible to settle this point, some fusion experiments were made with mixtures of silver chloride, bromide and iodide in varying molecular proportions[1], in the same way as that previously employed in the case of miersite (this vol. p. 43). The result of these experiments appeared to indicate that the limiting amount of iodide which could enter into isomorphous mixture with the chloride and bromide was reached for mixtures of the three in about equal molecular proportions (Cl : Br : I = 1 : 1 : 1), for in mixtures containing a less proportion of iodide there was no separation of iodyrite on solidification and cooling after fusion, but in mixtures containing a greater proportion of iodide small specks of doubly refractive iodyrite became more numerous as the proportion of iodide increased.

Sometimes, in the presence of a large excess of silver iodide, fine lamellar intergrowths of isotropic and birefringent material are seen, thus indicating that iodyrite may form intimate intergrowths with holohedral-cubic silver haloid in the same way that it does with miersite (this vol. p. 44). This further implies that at temperatures above 146° C. the amount of iodide which is capable of entering into the isomorphous mixture may exceed to any extent the limit given above. As in miersite, it would thus be possible to have natural crystals of cerargyrite containing an excess of silver iodide as an intimate intergrowth of iodyrite. In none of the natural crystals examined by us is, however, the limit exceeded, for there is no separation of iodyrite when they are fused and again cooled.

The natural crystals of cerargyrite and artificial mixtures in various proportions of silver chloride, bromide and iodide (the last not being in excess), as well as the pure chloride and bromide, all behave in much the same way when fused and again cooled on a microscope slide. They all show the same prominent crystalline structure marked out by two sets of rods and bars, and are isotropic or only feebly birefringent. This fusion method is therefore of no help for purposes of distinguishing the different kinds of cerargyrite.

[1] G. F. Rodwell has determined the specific gravity, melting point and coefficient of expansion of such artificial mixtures (Proc. Roy. Soc., 1876, vol. xxv, p. 292; Phil. Trans., 1883 (1882), vol. clxxiii, p. 1139).

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In view of the fact that in the holohedral-cubic silver haloids the chloride and bromide can form isomorphous mixtures in indefinite proportions, and that the iodide can also enter into isomorphous mixture with them in a very varying though limited amount, the present system of classification into a number of arbitrary and apparently disconnected species appears somewhat unsatisfactory. We propose therefore to include all the holohedral-cubic silver haloids under the common group-name of cerargyrite and to use the names 'chlorargyrite,' 'bromargyrite,' 'embolite,' and 'iodembolite' to indicate sub-species depending on varying proportions of chloride, bromide and iodide.

The horny character is common to the whole group, and, as previously mentioned, the name hornsilver was not originally applied merely to the pure chloride, for some of the characters in the older text-books (colour, &c.) attributed to cerargyrite show that at any rate chlorobromides, as well as pure chloride, were included. Portions of these old descriptions, however, appear to have been handed down with too little discrimination, so that they now figure in modern text-books as characterizing the pure chloride. For this reason some of the characters, such as colour and specific gravity, for the sub-species chlorargyrite, embolite and bromargyrite require a certain amount of revision.

As regards colour, the result of the qualitative examination given in the table on p. 177, together with that of the quantitative analyses, suggests that the absolutely pure chloride is colourless or grey, that embolites are mainly greenish-grey, that a decided yellow colour is only apparent when the mineral contains an appreciable amount of iodide, and that when the latter is in large amount (near 20%) the colour is distinctly orange-yellow.

As regards specific gravity, the value 5·552 for chlorargyrite given in the text-books dates back to the time of Mohs (1824). A determination was therefore made of the specific gravity of the pure chlorargyrite, (No. 54819) from the Florida mine, Taltal, Chili, in which the qualitative examination had shown the absence of bromine and iodine. The result of the determination made on 0·6516 gram of material was 5·556 (G. T. P.) as the weight of 1 cc. at 14° C. The specific gravities for embolite, 5·31 to 5·43 of Domeyko, and 5·53 of Yorke, should no longer appear in text-books, as they are obviously too low.

The hardness of 1–1·5 given for chlorargyrite and embolite is too low, for we find that all the specimens which we have examined scratch gypsum with ease, but do not scratch calcite; the hardness is therefore $2\frac{1}{2}$.

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The crystal-forms given in the text-books also require confirmation. The forms {211} and {221}, for example, have evidently been copied through Hausmann (1847) from Lévy (1837), who however gives {411} and {441}. On the several crystals examined by us only the cube and octahedron are developed.

The general characters of the Cerargyrite Group may now be summarized as follows:—

Holohedral-cubic. Common forms, the cube, $a\{100\}$, and octahedron, $o\{111\}$. Twinning rare; twin-plane o (111).

Cleavage, none. Fracture, uneven to sub-conchoidal. Tough and sectile. Hardness = 2½. Specific gravity, variable, depending on chemical composition.

Lustre, resinous to adamantine. Translucent. Colour, variable, and depending on chemical composition, but in all cases altered on exposure to light (differing in this respect from iodyrite and miersite). Optically isotropic.

Chemical composition, Ag(Cl,Br,I), the relative amounts of the isomorphous constituents, Cl, Br and I, varying considerably. On this variation the following *sub-species* are based:—

Chlorargyrite, AgCl. Grey or colourless. Sp. gr. = 5·556.

Bromargyrite, AgBr. Greenish-grey.

Embolite, Ag(Cl,Br). Greenish-grey.

Iodembolite, Ag(Cl,Br,I). Greenish-yellow to orange-yellow.

The results of the present investigation on the silver haloids and a previous investigation by one of us on marshite, miersite and iodyrite (this vol. pp. 38–53. See also p. 188 in this number) show that silver iodide may crystallize under one or other of the following four conditions. At temperatures below 146° C. (assuming atmospheric pressure) pure silver iodide crystallizes as rhombohedral iodyrite, while above this temperature tetrahedral-cubic crystals (type (*b*), this vol. p. 46) are formed: it may also enter, to a certain extent, into isomorphous mixture with holohedral-cubic silver chloride and bromide; or again, with copper iodide, it may form tetrahedral-cubic crystals of the double salt 4AgI.CuI.

The silver haloids at present known to occur as minerals may therefore be classified under the three main species:—

Cerargyrite, Ag(Cl,Br,I), holohedral-cubic.

Iodyrite, AgI, hemimorphic-rhombohedral.

Miersite, 4AgI.CuI, tetrahedral-cubic.

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The Identity of Kilbrickenite with Geocronite: and Analyses of Miersite, Marshite, and Copper-pyrites.

By G. T. Prior, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read February 4, 1902.]

(1) The Identity of Kilbrickenite with Geocronite.

THE mineral kilbrickenite was analysed, described and named by Dr. James Apjohn in 1840[1]. The specimens which he examined were sent to him by Mr. P. M. Taylor, who conducted the mining operations at the Kilbricken mine in County Clare, where the mineral was discovered. Apjohn's analysis showed the presence of lead, antimony and sulphur in proportions corresponding fairly closely with the formula $6PbS.Sb_2S_3$. It was only in the preceding year that L. F. Svanberg had described a new mineral, geocronite[2], to which he assigned the formula $5PbS.(Sb,As)_2S_3$. The announcement of this new mineral appears to have escaped Apjohn's notice, since geocronite is not included in the list of sulphantimonites of lead with which he concludes his paper. Had he been aware of the existence of geocronite, he would probably not have ventured to found a new species on the result of an analysis of a massive mineral differing so little in composition from geocronite, for the numbers in his analysis really correspond to a formula intermediate between $5PbS.Sb_2S_3$ and $6PbS.Sb_2S_3$.

A priori therefore the identity of the two minerals seems highly probable, and in fact, in the earlier editions of Dana's 'System of Mineralogy,' kilbrickenite appears as a variety of geocronite. In later editions, however, and in other text-books the mineral is elevated to the dignity of a separate species.

Recently, through the kindness of Mr. J. J. Beringer, there has been placed at my disposal for analysis material from specimens of kilbrickenite contained in the Museum of the Mining School at Camborne, Cornwall. The genuineness of these specimens is guaranteed by the fact that they form part of the Taylor Collection and are accompanied by two letters, one from Dr. Apjohn to Mr. P. M. Taylor giving the results of his

[1] Proc. Roy. Irish Acad., 1841, vol. i, pp. 469–73.

[2] Kongl. Vetenskaps-Acad. Handl. (for 1839), Stockholm, 1841, p. 184; Ann. Phys. Chem. (Poggendorff), 1840, vol. li, p. 535.

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analysis of kilbrickenite, and the other from Mr. P. M. Taylor to Mr. John Taylor stating that he was sending him 'two good pieces of kilbrickenite together with Dr. Apjohn's letter and analysis.'

Physical Characters.—The two specimens of kilbrickenite belonging to the Camborne Mining School are precisely similar in appearance to specimens of massive geocronite in the British Museum from the original locality, Sala, Sweden. They show the same lead-grey colour with metallic lustre, and indications here and there of an imperfect cleavage on which can be seen faint striations in two rectangular directions. The hardness is 3, and the mineral is only slightly brittle. The specific gravity (weight of 1 cc. at 21° C.) of the material used in the analysis is 6·45, practically the same as that of geocronite from Tuscany analysed by Kerndt.

Chemical Composition.—Of the two specimens, one showed some galena in association with the kilbrickenite, but the other appeared to be homogeneous and free from galena. The material used in the analysis was therefore taken from the latter specimen.

The mineral was decomposed in chlorine, the lead was determined as chloride, the arsenic as pyroarsenate of magnesia, and the antimony as sulphide after heating to 260° in carbonic acid. The sulphur was determined in a separate portion by fusion with sodium carbonate and nitre.

Under I is given the result of the present analysis of geocronite ('kilbrickenite') from Kilbricken mine, Co. Clare; under II that of a recent analysis by G. D'Achiardi[1] of crystals of geocronite from Val di Castello, Tuscany; and under III the theoretical composition required by the formula $5PbS.Sb_2S_3 + 5PbS.As_2S_3$.

	I. (Kilbricken).	(Atomic ratios).		II. (Val di Castello).	III. (Theoretical).
Pb . . .	68·49	·3318		70·02	69·62
Sb . . .	9·13	·0758	·1370	7·78	8·07
As . . .	4·59	·0612		4·47	5·05
S . . .	17·20	·5376		17·57	17·26
	99·41			99·84	100·00

Weight of material used in analysis = 0·8286. $PbCl_2$ = 0·7620; Sb_2S_3 = 0·1051; $Mg_2As_2O_7$ = 0·0780. Weight of material used in sulphur determination = 0·5020. $BaSO_4$ = 0·6279 gram.

The numbers obtained correspond fairly closely with the formula $5PbS.(Sb,As)_2S_3$.

[1] Atti Soc. Toscana Sci. Nat., 1901, Mem. vol. xviii.

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The result of the analysis therefore, combined with the correspondence in physical characters, leaves no room for doubt that kilbrickenite is identical with geocronite.

The most important difference between the present analysis and that of Apjohn is the presence of arsenic. In his paper, Apjohn makes no mention of having tested qualitatively for arsenic, nor would his method of quantitative analysis have led to its detection, since he simply precipitated the antimony by sulphuretted hydrogen and weighed the precipitated sulphide after drying at 100°.

The percentage of arsenic (4·59) found in the Kilbricken mineral is very close to that found by Svanberg in the original geocronite from Sala (4·70), and that by Kerndt (4·72) and more recently by D'Achiardi (4·47) in the mineral from Tuscany. This fact that the mineral from three widely different localities contains approximately the same percentage of arsenic lends considerable support to D'Achiardi's suggestion that geocronite is the double salt $5PbS.Sb_2S_3 + 5PbS.As_2S_3$.

It must be pointed out, however, that the acceptation of this idea would necessitate the reference to another species of the 'schulzite' from Meredo, Spain, analysed by Sauvage [1], and the mineral from Björkskogsnäs, Sweden, analysed by Nauckhoff [2], both of which contain no arsenic.

(2) Analysis of Miersite.

Miersite, the new iodide of silver and copper, has been described by Mr. L. J. Spencer in this volume (p. 41). The material, on which the following analysis was made, was collected by him from one specimen (No. 83466) in the British Museum, and was very carefully picked out under the lens and microscope until it showed no trace of impurities.

On this specimen, from Broken Hill, New South Wales, the yellow crystals and crystalline aggregates of miersite rest on a matrix of granular quartz containing copper-glance and a few brown garnets. A little limonite is dusted over the matrix and the miersite, and to remove this the material used in the analysis was digested in warm, dilute nitric acid.

The mineral was decomposed by means of zinc and sulphuric acid. The precipitated silver and copper were dissolved in nitric acid, and the silver determined as chloride and the copper as sulphide. A double precipitation of the copper with sulphuretted hydrogen in fairly acid solution was necessary in order to obtain the sulphide of copper free from zinc. The iodine in solution as zinc iodide in the filtrate from the silver

[1] Ann. des Mines, 1840, ser. 3, vol. xvii, p. 525.

[2] Geol. För. Förh. Stockholm, 1872, vol. i, p. 88.

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and copper was liberated by nitrous acid, dissolved in carbon bisulphide, and determined by titration with sodium thiosulphate in the usual way. The following are the results obtained :—

		Atomic ratios.
Ag . . .	38·17	·353 or 4
Cu . . .	5·64	·090 „ 1
I	56·58	·446 „ 5
	100·39	

Weight of mineral used in the analysis = 0·4328; I = 0·2449; AgCl = 0·2195; Cu_2S = 0·0306 gram.

Specific gravity (weight of 1 cc. at 28° C.) = 5·640.

The numbers agree very closely with the formula 4AgI.CuI, to which Mr. Spencer had been led by means of fusion experiments (see this volume, p. 44).

(3) Analysis of Marshite.

Material for the following analysis, free from impurities, was collected from one specimen (No. 84520) in the British Museum by Mr. L. J. Spencer, who has described the physical characters of the mineral in this volume (p. 38).

The marshite on this specimen, from Broken Hill, New South Wales, occurs as numerous fairly large flesh-red tetrahedra (crystals of 'type B,' *loc. cit.* p. 40), encrusting platy psilomelane, which in its turn rests upon an incoherent mixture of cerussite, limonite and garnet with a few bright octahedra of cuprite.

The mineral was decomposed by digestion (several times repeated) with a strong solution of caustic soda. In the residue after filtration the silver was determined as chloride and the copper as sulphide, while the iodine in the soda solution was liberated with nitrous acid and determined by titration with sodium thiosulphate. In the filtrate from the iodine a little copper was precipitated by sulphuretted hydrogen. The following are the results obtained :—

		Atomic ratios.
Cu . . .	32·35	·513
Ag . . .	1·19	·011
I . . .	65·85	·520
	99·39	

Weight of mineral used in the analysis = 0·4808; I = 0·3166; AgCl = 0·0076; Cu_2S = 0·1949 gram.

Specific gravity (weight of 1 cc. at 28° C.) = 5·590[1].

[1] Recently W. Spring (Zeit. f. Anorg. Chem. 1901, vol. xxvii, p. 308) has given

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The numbers correspond closely to the formula CuI. The silver is probably due to a slight isomorphous admixture of miersite.

(4) Analysis of Copper-pyrites.

The specimen (No. 63230) of copper-pyrites, the result of the analysis of which is given below, is from Wheal Towan, St. Agnes, Cornwall. It was selected for analysis owing to the peculiarities of its crystals. These, although in other physical respects like copper-pyrites, are in habit apparently cubic and show what seem to be dodecahedral faces. The crystals (measuring about 8 cm. across, and associated with small crystals of quartz and mispickel on a matrix of quartz and chlorite) are so rough and striated that only measurements with the contact goniometer are possible: the angles between the faces intersecting in apparently dodecahedral edges were mostly about 60°. The striations are parallel to the longer diagonal of the rhombic faces, and in the opinion of Mr. L. J. Spencer these crystals are similar to the complex twins of stannite recently described by him in this volume (pp. 54–65) and figured in plate II, fig. 3, i. e. they are probably interpenetrant symmetric twins composed of three individuals with e (101) as twin-plane. The appearance of the fractured surface of the crystals, which exhibits a very delicate rippling, is also suggestive of repeated twinning.

In the analysis the copper was determined as sulphide, the iron as oxide, and the sulphur in a separate portion as barium sulphate. The results obtained are:—

		Atomic ratios.
Cu . . .	33·60	·5442 or 1
Fe . . .	30·92	·5533 „ 1·02
S . . .	34·90	1·0912 „ 2·04
	99·42	

Weight of mineral used in analysis = 0·8170; Cu_2S = 0·3520; Fe_2O_3 = 0·3608. Weight used for sulphur determination = 0·4092; $BaSO_4$ = 1·0390 gram.

Specific gravity (weight of 1 cc. at 22° C.) = 4·17.

The result of the analysis shows that the mineral is perfectly pure copper-pyrites, the numbers agreeing very closely with the usual formula $CuFeS_2$. The peculiarities in crystal structure have therefore no connexion with anomalies in chemical composition, nor with any admixture of impurities such as iron-pyrites.

for the specific gravity of precipitated cuprous iodide the value 5·631, as the mean of four determinations, varying from 5·563 to 5·677, made on air-dried, on fused, and also on compressed material.

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OBITUARY.

Nils Adolf Erik Nordenskiöld.

The death of Professor Baron A. E. Nordenskiöld at Stockholm, on August 18, 1901, deprives our Society of a distinguished honorary member, elected in 1877 soon after its foundation. His nephew, Dr. Otto Nordenskiöld, writes: 'His death was absolutely sudden: the same day he was working in his laboratory, occupied with great plans in his mineralogical and chemical work.'

Nordenskiöld was born at Helsingfors on November 18, 1832, of a Swedish family possessed of scientific attainments. His father, Dr. Nils Gustaf Nordenskiöld, also well-known as a mineralogist, was director of the Department of Mines in Finland, and the son accompanied his father on many mineralogical excursions, including one to the Urals in 1858. In this way young Nordenskiöld became an enthusiastic student and collector of minerals. In 1849 he entered the University of Helsingfors, applying himself to science and spending his vacations in visiting the rich mineral localities of Finland. His first paper 'on the crystalline forms of graphite and chondrodite,' written in 1855, was a dissertation for the degree of licentiate; in the same year he published his book on the Minerals of Finland, a second edition of which appeared in 1863. Immediately after taking his degree he was appointed Curator of the Mathematico-Physical Faculty and to a post in the Mining Office, but was dismissed in the same year on account of a political speech distasteful to the Russian Government. This rendered it advisable for him to go abroad, and his time was spent working at mineral analysis in Rose's laboratory at Berlin. In 1857 he returned to Helsingfors to take his degree of master and doctor; at the graduation ceremony, which was attended by a deputation from the Swedish Universities, the young doctor again expressed his sympathies too plainly, and as a result was banished from the country.

He then settled in Sweden, and as a geologist accompanied the Swedish expedition to Spitzbergen in 1858. After his return he was appointed professor and director of the mineralogical collections of the State Museum at Stockholm in succession to Mosander. This appointment gave him opportunities for investigating the many rare minerals for which the Scandinavian peninsula is remarkable, and the results of

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his work in this direction are recorded in a long list of mineralogical papers. Quite recently, in a paper read before the Geological Society of London, of which he was a Foreign Member, he has given an historical review of Scandinavian minerals containing rare elements. About half of the twenty-six minerals discovered and named by him have withstood the test of subsequent examination, and now rank as well-defined species, of which, among others, may be mentioned crookesite, thaumasite, kainosite, ganomalite, tapiolite, and hydrocerussite. The peculiar borate of calcium and tin, nordenskiöldine, bears his name.

It was, however, as an Arctic explorer that Nordenskiöld achieved fame. He several times visited Spitzbergen, where he made important geological collections. During one of his two expeditions to Greenland he discovered, and brought back in 1870, large masses of the now celebrated Ovifak (Disko) iron, formerly thought to be meteoric, but now known to be of terrestrial origin; he further made important observations on the cosmic dust (cryoconite) which accumulates on the inland ice. During the memorable voyage of the *Vega* in 1878–1880 he accomplished the navigation of the North-East Passage, a feat many times before attempted, thus being the first to circumnavigate Europe and Asia. On his return he received many honours, including a Swedish baronetcy.

NOTES.

THE fine private collection of minerals and meteorites, comprising some 10,000 specimens, brought together during a period of thirty-five years by Mr. Clarence S. Bement, of Philadelphia, has recently been purchased by Mr. J. Pierpont Morgan and presented to the American Museum of Natural History at New York. Only shortly before Mr. Morgan had purchased for the same museum, of which he is a trustee, a large collection of precious stones and pearls which was on exhibition by Messrs. Tiffany and Co., of New York, at the Paris Exposition of 1900.

A Mineralogical Society (Wiener Mineralogische Gesellschaft) was founded at Vienna on March 27, 1901. Reports of the monthly meetings, excursions to mineral localities, and visits to museums, will be found in the 'Mineralogische und Petrographische Mittheilungen,' the periodical commenced in 1871 by Professor Tschermak, who is the first president of the new society.

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We regret to note the death on July 8, 1901, of Karl Adolf Moberg, who since 1886 has been a member of our Society. He was born at Helsingfors on September 15, 1840, and, after graduating at the University, entered the Government Department of Mines. He was officially connected with the Mint, and for many years was director of the Geological Survey of Finland.

Among other deaths recently announced are:—

Julius Albin Weisbach (1833–1901), who in 1886 succeeded Breithaupt as Professor of Mineralogy in the Mining Academy at Freiberg.

Thomas Egleston (1832–1900), who took an important part in the founding, in 1864, of the School of Mines of the Columbia University at New York, in which institution he was Professor of Mineralogy and Metallurgy until 1897.

C. August Tenne (1851–1901), Docent in the University of Berlin and Curator in the Museum für Naturkunde, Berlin.

Edouard Jannettaz (1832–1900), Assistant in the Mineralogical division of the Natural History Museum at Paris, and past-President of the French Mineralogical Society.

A large octahedral crystal of diamond from the Cape, recently presented to the Natural History Museum at Vienna by Georg von Haas, was described by Professor F. Berwerth in Band xix (1900, p. 340) of Tschermak's 'Mineralogische und Petrogr. Mittheilungen.' It weighs 82·5 Vienna carats, and in the direction of the axes the dimensions are from 2·4 to 2·8 centimetres; and it was thought by Professor Berwerth to be the largest crystal of diamond exhibited in any public collection. It may, however, be noted that the 'Colenso' diamond, presented to the British Museum (Natural History) by John Ruskin in 1887, weighs 129⅔ carats.

A selection from a large series of well-crystallized minerals, mainly calcite and barytes, from the haematite mines of West Cumberland, is at present exhibited in the recent acquisition case in the Mineral Gallery of the British Museum at South Kensington.

Professor R. Brauns, in a recent number of the 'Centralblatt für Mineralogie, &c.' (1901, p. 134), points out that the characters given for conchite, a supposed new modification of calcium carbonate described in this Magazine (vol. xii, p. 368), are sufficiently close, considering the unsatisfactory nature of the material available for examination, to those of aragonite to suggest the identity of conchite with that species. The

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same conclusion has been independently arrived at by Professor H. Vater (Zeits. Kryst. Min., 1901, vol. xxxv, p. 149), who further gives reasons for considering that ktypeite also is probably identical with aragonite.

A new issue (fourth thousand) has been received of Professor A. H. Church's useful and well-known little Handbook on Precious Stones. Except for one or two minor alterations, the text remains the same as before, but two pages of supplementary notes are given at the beginning of the volume.

We have received from Mr. H. Y. L. Brown, F.G.S., the Government Geologist of South Australia, various reports and a Handbook of Mining which have been issued for free distribution by the Department of Mines. The Handbook of Mining gives a brief account of the mineral resources of the State, together with a summary of the Mining Acts and regulations, and it is accompanied by four large maps showing the distribution of metallic minerals. From the same source we have also received an excellent geological map of South Australia on a scale of 16 miles to the inch.

REVIEW.

The Mineralogy of Scotland. By the late M. Forster Heddle, M.D., F.R.S.E., Emeritus Professor of Chemistry, St. Andrews. Edited by J. G. Goodchild, H.M. Geological Survey, F.G.S. Two vols. (pp. lviii and 148, viii and 247, 30 text-figs. and 120 plates). Edinburgh: David Douglas. 1901. (Price 36*s. net.*)

These two handsome volumes form a fitting memorial to Professor Heddle, so well known for the enthusiasm and energy with which for many years he studied the minerals of his native country. No one was better acquainted with the mineral localities of Scotland, nor has any one laboured more assiduously at the chemical analysis of Scotch minerals. The many papers, some of great length, published in the pages of this Magazine, are sufficient testimony to his ceaseless activity in this direction. For many years he had been collecting material which some day he hoped to publish as a connected whole, but at his death[1] in 1897 this work was unfortunately still incomplete. In handing over his voluminous notes and drawings to his son-in-law, Mr.

[1] For an obituary notice of Dr. Heddle see this Magazine, vol. xii, p. 38.

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Alexander Thoms, Heddle expressed the wish that they should be published as a book, and the laborious work of editing this material has been ably performed, considering the difficult nature of the task, by Mr. J. G. Goodchild. This has been done with as little alteration as possible, the aim of the editor being to complete the work as Heddle would himself have done. In this work of completion free use has been made of the large collection of Scottish minerals brought together and arranged by Heddle himself, and now under the charge of Mr. Goodchild in the Edinburgh Museum of Science and Art.

In addition to the main part of the work, for which Mr. Goodchild is responsible, Mr. Thoms contributes a memoir of Dr. Heddle, as well as lists of minerals found in each of the counties of Scotland, while Mr. James Currie gives (vol. i, pp. xxxvii–l) a very complete and useful list of Scottish pseudomorphs, with the localities at which they have been found.

The bulk of the volumes is occupied by particulars of the occurrence of just over 200 mineral species in Scotland. Every locality at which each species has been found is enumerated, and in each case is stated the kind of rock in which the mineral occurs, and the other species with which it is associated, together with a brief description of the mineral itself, including in most cases the combinations of forms observed on the crystals. For information concerning Scottish mineral localities, this treatise far surpasses anything hitherto attempted, and it will long remain a standard work of reference. Mr. Goodchild has greatly added to its value in this respect by a very full synonymic index of locality names, in which he has been at great pains to give the exact situation of each place; the various mineral species found at each locality are also enumerated.

While the topographical portion is very complete and of much value, that dealing with crystallography is less satisfactory. Here the editor has been at a disadvantage owing to the different systems of notation employed by Heddle at various times, and apparently because of the incomplete state in which this portion was left at the author's death. Whether the numerous forms have been determined by mere inspection of crystals or by actual goniometric measurement does not appear to be stated; at any rate for only a few species are tables of *calculated* angles given, these being in some places the face-angles and in others the normal-angles. Under calcite is given a long list of 266 forms, which surely have not all been observed on Scotch crystals of this mineral. To the crystallographic portions Mr. Goodchild has added several beautiful

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plates giving stereographic or gnomonic projections for the more commonly occurring crystallized species. These, though excellent in themselves, are open to the same objection as is the list of forms of calcite noted above, since in representing all the forms known for each species they seem rather out of place in a 'Mineralogy of Scotland.'

The most striking feature of the volumes is the 120 excellent plates, one of which is a portrait of the author; most of the others contain eight figures of crystals, beautifully and clearly drawn. In the preface we find the statement that 'The author died before making a final selection of the illustrations, and it has therefore been deemed advisable to have these all engraved just as they left his hands, even though some of them appear to have been taken from other sources.' There is thus no guarantee that all of these numerous figures refer to Scottish crystals, and it is possible that some of them may have been drawn by the author to illustrate an account of minerals in general, as for example his article on Mineralogy in the ninth edition of the 'Encyclopædia Britannica.' Several of the figures seem familiar; some of those of chalcopyrite, for example, are exact copies of Haidinger's figures of Cornish crystals.

In many cases very little account is taken of the work of other authors except as far as regards occurrences and chemical analyses; and the descriptions of some typically Scotch minerals, for example, greenockite, are consequently rather disappointing.

In works of this kind errors and omissions are almost unavoidable, and the present is by no means an exception in this respect. The way in which Dana has been rigidly followed has led to one or two curious mistakes. The only index of mineral names includes also those of minerals not found in Scotland, and is unfortunately not accompanied by references to pages. In the absence of any list of the abbreviations and signs of various kinds which are made use of, it is not always easy to discover their meaning.

ABSTRACTS.

Constitution of Silicates (W. Vernadsky, Zeits. Kryst. Min., 1901, vol. xxxiv, pp. 87–66).—In this contribution to the study of the theoretical constitution of silicates the author first points to the analogy between the part played by carbon in organic chemistry and the part played by silicon in mineralogical chemistry. Admitting that the investigations of the latter have not led at present to results which

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justify a fully developed theory, he puts the conclusions from collected data into the form of a suggestion towards the solution of the problem of the constitution of natural silicates.

For his present purpose the author puts aside certain silicates (amongst them those containing haloids and metalloids) as not admitting at present of conjectural structural formulae, and deals only with silicates which may be regarded as isomorphous mixtures consisting of Si, O, H, and metals. He calls the *principal* constituent of such an isomorphous mixture (and to which he attributes his structural formula) the 'Lösungsmittel.'

He divides the silicates under consideration into two classes:—

I. Those containing no metal-oxide of the type $R_2'''O_3$. These he calls simple silicates.

II. Those containing such a metal-oxide. These he calls alumosilicates (ferro-, chromo-, &c., according to their composition).

Among the reasons for the sharp distinction between these classes, the following are alleged. There is no transition from one to the other so far as the 'Lösungsmittel' is concerned. A metal of the oxide RO is never replaced by aluminium. The weathering of class I gives hydrated silica and silica, while the weathering of class II rarely gives hydrated silica, and generally gives clays and chloritic minerals. Class I can *always* be regarded as salt or hydrate, or some more or less complicated addition product of salts or hydrates of a *known* silicic acid, while it is difficult to reconcile class II with any known or conceivable silicic acid or hydrate. The writer gives reasons for regarding class II rather as anhydride, hydrate or salt (and their various derivatives or addition products) of complex alumosilicic acids.

Class I is divided into subdivisions which the writer formulates thus:—

(i) Hydrates. Represented by opal (group 1).

(ii) Orthosilicates, $(RO)_2 = Si = (OR)_2$, represented by the olivine group (salts) (2), sepiolite (acid salt) (3), and various minerals of which he takes chondrodite (4), serpentine (5), chrysocolla (6), noumeaite (7), and calamine (8) as typical, which are all called addition products of orthosilicates.

(iii) Metasilicates, $(RO)_2 = Si = O$. Represented by the pyroxene and amphibole groups (9), talc (acid salt) (10), and apophyllite (addition product?) (11).

Attention is called to the separation of gelatinous silica from the orthosilicates, of powdery silica from the metasilicates, and of 'slimy' silica where the mineral can be regarded as a mixture of both.

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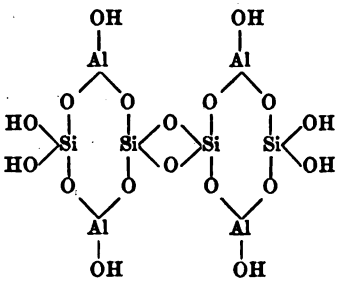
Class II is subdivided as follows:—

(i) Complex anhydrides and their addition products. Represented by the sillimanite group (12.).

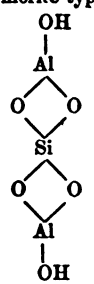
(ii) Complex acids and hydrates and their addition products. Represented by the kaolin group (13), to which the writer attributes the following structure, which will be noticed to resemble an addition product on the 'mica type' noticed below.



$(H_2Al_2Si_2O_8 . H_2O$, Kaolin).

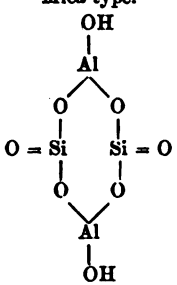
(iii) Complex salts and addition products; in which the writer recognizes two types:—

Chlorite type.



$(RO . Al_2O_3 . SiO_2)$

Mica type.



$(M_2O . Al_2O_3 . p\,SiO_2$, where $p = 2, 4, 6$, etc.)

The chlorite type is represented by staurolite (14), various minerals of which he takes clintonite (15), chlorite (16) as typical addition products, and melilite (17) (classed as doubtful).

The mica type is represented by the mica group (18), and various minerals which represent addition products, and of which the writer takes the following as typical: leucite (19), felspar (20), petalite (21), nepheline (22), carpholite (23), scapolite (24), epidote (25), garnet (26), vesuvianite (27), prehnite (28), cordierite (29), and zeolites (30). For these the following structural formulae are given:—

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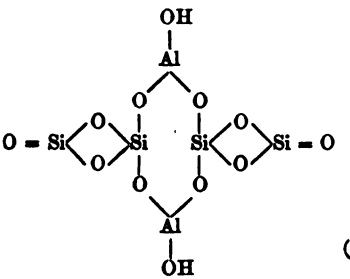
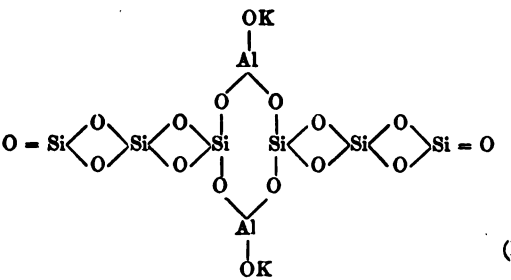
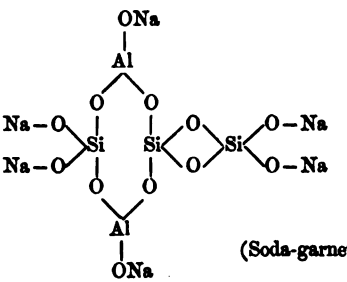


(Leucite)



(Felspar.)



(Soda-garnet = lagoriolite.)

The writer completes his classification by adding to his simple silicates (A) and alumosilicates (B), to which he attributes structural formulae as above, the following classes which he does not undertake at present to describe by a graphic structure, viz.:—beryllium silicates (C), borosilicates (D), cerium and yttrium silicates (E), titanosilicates (F), zirconosilicates (G), and uranosilicates (H). W. P. B.

The Structure of Crystals: Part I, Report on the Development of the Geometrical Theories of Crystal Structure, 1666–1901. (Drawn up by W. Barlow and H. A. Miers, assisted by G. F. Herbert Smith. British Association for the Advancement of Science, Glasgow Meeting, 1901, Section C. 41 pp.)—In this Part is considered the manner in which the

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material constituting the crystal is put together; a side of the subject which seems to have reached something like finality. The historical development of the subject is sketched, and the more important contributions are discussed in detail. Early speculations that the forms of crystals may be imitated by the packing together of similar bodies, Steno's observation of the identity of the mutual inclinations of corresponding faces of rock-crystal in different specimens, and Romé de l'Isle's important discovery, that the various shapes of a crystal may all be deduced from the same primitive form, lead up to the epoch-making writings of *Haüy*. From the phenomena of cleavage he deduces that crystals are built up of a regular accretion of the ultimate parts, *molécules intégrantes*, immediately derivable from the cleavages of the substance. Secondary faces are supposed to be due to the deposition of successive layers on each face of the original nucleus to form regular steps, so that their boundaries form planes which truncate the edges or corners of an enlarged figure due to a uniform growth of the nucleus. In cases where the *molécules intégrantes* are not parallelepipeda, Haüy regards them as aggregated to form parallelepipedal groups, *molécules soustractives*, which, however, are merely geometrical conceptions to elucidate the growth of secondary faces and may be only fictions. This regular growth of secondary faces leads at once to the great Law of the Rationality of Intercepts, more familiarly known as the Law of Rational Indices. His theories are not free from objection; nevertheless they place the study of crystal structure on a sure foundation. His *molécules intégrantes* are especially interesting in the light of later research, since they reduce the problem to the partitioning of space into similar polyhedra which are not necessarily parallel.

The importance of Haüy's law of rational indices was speedily recognized. Weiss and Mohs employed it to place in a clear light the ascertained facts regarding the outward form and the optical properties of crystals. Hessel in a remarkable work, which remained overlooked for sixty years, showed that this law limits the number of possible types of crystals to thirty-two. Nearly forty years later Gadolin came independently to the same result by similar reasoning. This method leads to a curious case of pseudo-trigonal symmetry which has attracted some attention.

All the writers immediately subsequent to Haüy disregarded the shape of the constituent particles and confined their attention to their centres, which they supposed to be arranged on a parallelepipedal network or space-lattice. In this simple guise the problem was discussed by

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Frankenheim. Rigid proofs of his geometrical investigations were supplied by *Bravais*, who also considered the effect of the individual symmetry of the units on that of the whole structure. He employed the mathematical conception of a coincidence-movement, and virtually studied the possible varieties of axes of symmetry, and the possible ways in which they can exist in a system whose various parts can be derived from each other by movements of translation. He found fourteen different lattices (Frankenheim gave fifteen, but two are really identical). Bravais explains hemihedrism as due to the symmetry of the constituent unit, and employs the phenomenon of cleavage as a clue to the internal symmetry. Bravais marks a very important epoch: the knowledge of the properties of the space-lattice first provides a single principle capable of explaining at the same time the law of rational indices, the homogeneity of a crystal, and the main features of crystalline symmetry.

A most important departure is marked by Wiener, who laid down the principle that regularity in the arrangement of identical atoms is presented when every atom has the remaining atoms arranged about it in the same manner; thus no longer laying stress on sameway orientation. Jordan in a mathematical paper discussed the general problem of groups of movements. This is of vital importance in studying the manner in which the various parts of a structure are symmetrically related to each other; one being derived from another by an imaginary movement. In his influential works *Sohncke*, employing Wiener's principle and Jordan's method, obtains what he calls 'a regular point system.' He introduces screw-movements, which may be said to result in two interpenetrating congruent lattices, and finally arrives at sixty-five different systems. As far as it goes his method is complete, but, as Wulff pointed out, it fails to account for the symmetry displayed by dioptase, and he is, like Bravais, driven to make the symmetry of a system depend partly on the arrangement of the ultimate parts and partly on the configuration of these parts.

The introduction of the principle of mirror-image repetition marks the last great advance in the development of the geometrical theory. The credit is shared by Curie, Schönflies, and Fedorow. The first named, however, only applied it to the derivation of the thirty-two classes of central symmetry. Schönflies and Fedorow arrived independently at the 230 groups of crystal structure, in which all the thirty-two classes are represented. *Schönflies* shows that any homogeneous arrangement has the elements of symmetry of one of these classes, and may at the same time be referred to one of the translation

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groups, or space-lattices. By applying these methods and determining which of the resulting groups are identical, he finally arrives at the number mentioned. The later part of his great work, 'Krystallsysteme und Krystallstructur,' is occupied with the question of space-partitioning. He discusses at length the 'elementary cell,' which is such that all the elements of symmetry lie on its surface; if repeated about certain of these elements a symmetrical space-unit, the 'complex cell,' is obtained. A corresponding crystalline structure is derived by furnishing each elementary cell in a similar manner with contents of any nature. *Fedorow* adopted similar reasoning but somewhat different analytical methods. He studied the symmetry of finite solid figures in general, and, limiting the problem by a condition equivalent to the law of rational indices, obtains the thirty-two classes. In a later memoir he shows that space may be filled by parallelohedra or by stereohedra, which are identical or symmetrical figures, not necessarily parallel. When space is partitioned into differently orientated identically similar plane-faced stereohedra, these may be grouped together into sets, such that each set is a parallelohedron; further, the analogous points of the stereohedra constitute a regular point-system, just as the analogous points of the parallelohedra constitute a space-lattice. In his second treatise he deals with regular systems of figures and more directly approaches the problem of crystal structure. His definition is practically the same as that of Schönflies, and necessarily results in 230 groups; he also arrives at the 'elementary cell.' *Barlow* attacked the problem in a different manner. Proceeding from structures of lower to those of higher symmetry, he obtains Sohncke's sixty-five sets of coincidence-movements, and points out that to each of these corresponds a class of homogeneous structure which is not identical with its own mirror-image. From each of these groups he develops, where possible, others by repetition across centres of symmetry, planes of ordinary or gliding symmetry, and axes of alternating symmetry (the Sohncke axes remaining unchanged), and finally obtains 165 additional groups, giving 230 in all.

Kelvin has considered the problem of crystal structure mainly on the basis of the space-lattice, and arrived independently at the tetrakaidekahedron (Fedorow's heptaparallelohedron) as the most general form of cell belonging to a homogeneous space-partitioning. In the 'Boyle Lecture,' published in 1894, he discusses the relationship between the three aspects of the problem, namely, homogeneous assemblages of points, partitioning of space, and close-packing of similar bodies.

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In a subsequent Part it is proposed to discuss the various mechanical and physical conceptions which have been employed, and the definite structures ascribed to certain substances. G. F. H. S.

Optical Determination of Ores (J. Koenigsberger, Centralblatt Min., 1901, pp. 195–7).—Light reflected normally from the surface of an anisotropic substance becomes polarized to a small extent, while from an isotropic substance there is no polarization of the light. It is proposed to make use of this fact for distinguishing opaque minerals under the microscope, e. g. pyrites from marcasite, or magnetite from haematite. A bright crystal face or a cut and polished surface is illuminated by a vertical illuminator (a right-angled prism) inserted in the tube of the microscope above the objective, and any polarized light is detected by a Savart's plate and analysing nicol also placed in the tube of the microscope. The eye-piece of the microscope is replaced by a small telescope, and artificial light is used for illumination, since daylight is already partly polarized. Anisotropic crystals will then give rise to interference fringes, which will disappear and attain a maximum four times in a complete revolution of the microscopic-stage; and what corresponds to extinction angles in transparent crystals can be measured. If the crystal happens to be cut perpendicular to an optic axis no fringes will be seen unless the plate be tilted, when the difference between an isotropic and an anisotropic crystal can be seen on rotating the stage. Theoretically it is also possible to distinguish between uniaxial and biaxial crystals, but this would be difficult in practice. L. J. S.

The Stereographic Projection and its possibilities from a Graphical Standpoint (S. L. Penfield, Amer. J. Sci., 1901, ser. 4, vol. xi, pp. 1–24, 115–44, with 4 plates and 34 text-figures; also in part in Zeits. Kryst. Min., 1901, vol. xxxv, pp. 1–24).

The author points to the advantages, especially from an educational point of view, of solving crystallographic and other problems involving spherical trigonometry by graphical methods based on the principle of the stereographic projection. This method, although capable of a fair degree of accuracy, cannot of course take the place of exact numerical calculations, but it gives an easy means of checking results so obtained. It is also pointed out that for geographical maps and charts the stereographic projection would be much better than the incorrect methods of projection now in use, namely, the globular and Mercator's.

For the purpose of accurately plotting and taking measurements from

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stereographic projections the following mentioned protractors and scales have been designed and constructed:—

'Protractor No. I,' with stereographically projected degrees on the base-line, for plotting stereographic projections.

'Stereographic Protractor No. II,' with small vertical circles at every degree, for measuring the arcs of great circles.

'Stereographic Protractor No. III,' with great and small circles at every fifth degree.

'Stereographic Protractor No. IV,' with great circles at every alternate degree.

Protractor No. I is printed on cardboard, and the others are printed on thin sheets of celluloid so that they can be laid over the drawing for taking measurements. The complete set, which is patented in the United States and is placed on the market, includes sheets of drawing paper on which are printed a graduated circle, scales giving the radii of stereographically projected arcs of great circles and of small vertical circles, and scales of decimal parts and of stereographically projected degrees; also sheets printed with equatorial and meridian stereographic projections for map-drawing. All the scales, &c. are for a circle 14 cm. in diameter. For drawing the arcs of great circles of large radii a curved ruler is needed, of which a new form is figured and described. Points on the drawing are accurately located by a needle-point held against a half lens mounted on a stand. Finally, a set of instruments for blackboard demonstration is described.

In the original paper seven special cases are taken to illustrate the solution of spherical triangles, both right-angled and oblique, by graphical methods. The errors in the results obtained in these cases amounted to from 1′ to 15′, and on the average were only about five minutes.

L. J. S.

Pyrites and Marcasite (H. N. Stokes, Bull. U.S. Geol. Survey, 1901, No. 186, 50 pp.; Amer. J. Sci., 1901, ser. 4, vol. xii, pp. 414–20; Chem. News, 1902, vol. lxxxv, pp. 33 et seq.).—When pyrites and marcasite are not distinctly crystallized it is often difficult to distinguish between them, and the characters usually relied on for this purpose, namely colour, specific gravity, and ease of oxidation, are not altogether trustworthy. It is pointed out that the true colour of marcasite is tin-white, and that the usual bronze-yellow is due to tarnish.

The author has devised a chemical method for the discrimination of these minerals, and for their quantitative determination in mixtures.

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This method depends on the fact that when pyrites or marcasite is boiled with an excess of a solution of a ferric salt to complete reduction of the latter, the ratio of sulphur oxidized to mineral decomposed is perfectly definite and characteristic of each mineral, provided certain standard and easily controllable conditions are observed. With a boiling solution of iron ammonium alum containing 1 gram of ferric iron and 16 cc. of 25 per cent. free sulphuric acid per litre, the percentage of sulphur oxidized in pyrites is about 60·4, and in marcasite about 18 per cent. of the total sulphur. These figures are the characteristic oxidation coefficients, which depend, however, on the temperature and concentration of the solution. The determinations are made in an atmosphere of carbon dioxide, with specially designed apparatus.

An empirical curve for the oxidation coefficients of mixtures of pyrites and marcasite in known proportions gives a means of quantitatively determining the composition of naturally occurring mixtures. In this way it was shown, for example, that the nodules, often supposed to be marcasite, so abundant at Folkestone, are really pyrites; one specimen was found to contain pyrites 97, and marcasite 3 per cent.; and a pyritized ammonite, also from Folkestone, consisted of pyrites 88, and marcasite 12 per cent. L. J. S.

New Minerals from the Binnenthal Dolomite. The mineral sulpharsenites known to occur in the white crystalline dolomite of the Binnenthal, Switzerland, include sartorite ($PbS.As_2S_3$), rathite ($3PbS.2As_2S_3$), dufrenoysite ($2PbS.As_2S_3$), jordanite ($4PbS.As_2S_3$), and tennantite ($3Cu_2S.As_2S_3$, 'binnite'). To this list three more new minerals have recently been added, one of which, *baumhauerite*, is described by R. H. Solly in the present number (p. 151).

Seligmannite (H. Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, pp. 110–7).—Of this mineral, named after Herr G. Seligmann of Coblenz, only five crystals, varying in size from ½ to 4 mm., have been found, and it has been possible to make only a crystallographic examination. The colour, lustre, and brittleness are like those of the other Binnenthal sulpharsenites. In the habit of the rhombic crystals, in the forms present, the interfacial angles, and the repeated twinning on both prism planes (110), the mineral is closely allied to bournonite, with which it is no doubt isomorphous, being possibly the corresponding arsenic compound, $Cu_2S.2PbS.As_2S_3$.

Seligmannite, $a:b:c = 0{\cdot}92804:1:0{\cdot}87568$
Bournonite, „ $= 0{\cdot}93798:1:0{\cdot}89688$.

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Liveingite (R. H. Solly, Proc. Cambridge Phil. Soc., 1901, vol. xi, pp. 239–40).—Of this mineral, named after Prof. G. D. Liveing of Cambridge, only two crystals have been found, and the greater part of these have been used for a chemical analysis. The crystals are oblique, with a pseudo-rhombic habit; in the development of the dome zone there is a resemblance to rathite, while in the oblique prism zone ($\beta = 89° 45\frac{1}{2}'$) there is a resemblance to sartorite. The crystals are twinned on the orthopinacoid (100), and the two individuals are tarnished respectively green and red. Analysis by H. Jackson gave the following results:—

	Liveingite.	$4PbS.3As_2S_3$.	$5PbS.4As_2S_3$.
Pb . .	47·58	48·75	47·44
S . .	24·91	24·61	25·00
As . .	26·93	26·64	27·56
Fe . .	trace		
	99·42	100·00	100·00

In the original paper the formula is given as $4PbS.3As_2S_3$, but, as noted elsewhere (this number, p. 160), the results are in closer agreement with $5PbS.4As_2S_3$. L. J. S.

A simple Reaction for distinguishing Aragonite and Calcite (W. Meigen, Centralblatt Min., 1901, pp. 577–8).—The finely powdered material is placed in a dilute solution of cobalt nitrate, and this boiled for a few minutes. In the presence of aragonite there is formed a lilac-red precipitate of basic cobalt carbonate, while calcite remains white, or, in the presence of organic matter, becomes yellowish. Barium and strontium, but not magnesium, carbonate give the same result as aragonite, and calcium phosphate produces a blue precipitate. This reaction is made use of for the purpose of distinguishing calcite and aragonite in various animal and vegetable secretions of calcium carbonate.

These experiments have been repeated by G. Panebianco (Rivista Min. Crist. Italiana, 1902, vol. xxviii, pp. 5–12), who with Iceland-spar obtained a lavender-blue powder having the composition $CoCO_3 + \frac{3}{10}H_2O$, and with aragonite from Herrngrund a violet powder with the composition $CoCO_3 + \frac{1}{10}H_2O$.

This difference in behaviour of calcite and aragonite is the subject of some remarks of a theoretical nature by G. Wyrouboff (Bull. Soc. franç. Min., 1901, vol. xxiv, pp. 371–3). He attributes the greater stability of the physical particles of calcite to the higher degree of symmetry possessed by this mineral. L. J. S.

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Minerals of Roumania (P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, pp. 15–148).—A systematic description is given of all the mineral species known from Roumania, with notes on their occurrence at various localities. The paper is in French, and quotes much information from the somewhat inaccessible Roumanian journals. Several chemical analyses are given, and structural formulae are discussed, but there are no crystallographic descriptions. Two massive minerals are described under the new names badenite and brostenite: the former is considered to be a bismuthal variety of smaltite (or safflorite) with the formula $(Co,Ni,Fe)_2(As,Bi)_3$; the latter a hydrated manganite of iron and manganese of variable composition. L. J. S.

Cleopatra's Emerald Mines (D. A. MacAlister, Geographical Journal, 1900, vol. xvi, pp. 537–49).—An account is given of an expedition made in 1899 to the ancient emerald mines in the Jebel Sikait district (Northern Etbai), which is situated about 15 miles from the Red Sea in latitude 24° 40′ N. [The locality usually given in mineralogical text-books is Jebel (= Mount) Zabara, Zebarah, or Sabara, &c., in the Ababdeh desert, Egypt. This is about ten miles to the north of Jebel Sikait.] There are several scattered groups of primitive workings belonging to different periods dating back 2,000 years, and in the desert region are ruins of houses, temples, &c. The rocks of the district are gneisses and schists; the old mines are all in mica-schist or talc-schist. L. J. S.

Association of Epidote and Zoisite (P. Termier, Bull. Soc. franç. Min., 1900, vol. xxiii, pp. 50–64).—A case is described of the occurrence together of the trimorphous minerals epidote, α-zoisite and β-zoisite (see Abstract, Min. Mag. xii. 215). The 'green rocks' of Mount Pelvas (or Paravas), on the Franco-Italian frontier, contain veins and patches of white prehnite in which are embedded prisms of pale-green epidote and fine needles of very pale rose-coloured zoisite. The zoisite has the optical characters of α-zoisite, but sometimes a little β-zoisite is intergrown with it. At times there are also regular intergrowths of epidote and zoisite, with a definite crystallographic orientation between the two minerals: this indicates that the crystalline structures of epidote and zoisite must be closely related. L. J. S.

Synchysite, a new Mineral allied to Parisite (G. Flink, Bull. Geol. Inst. Univ. Upsala, 1900 (1901), vol. v, pp. 81–7).—This mineral, from Narsarsuk in South Greenland, discovered and analysed by

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G. Nordenskiöld in 1894, and again examined by Flink in 1900 (this vol. p. 94, abstract), has previously been referred to parisite, since in its characters it agreed to a certain extent with the parisite of Muso, Colombia. The true characters of the Muso parisite were, however, somewhat doubtful until recently, when S. L. Penfield and C. H. Warren (Amer. Journ. Sci., 1899, ser. 4, vol. viii, p. 21), in connexion with their description of the newly discovered parisite from Ravalli County in Montana, made a new analysis of the Muso mineral. The latter results prove that the Greenland mineral differs from parisite, and for it the new name synchysite (*συγχυσις*, confounding) is now proposed. The following are the main characters which distinguish the two species:—

	Synchysite.	Parisite.
Chemical formula .	$CeFCa(CO_3)_2$	$(CeF)_2Ca(CO_3)_3$
Cleavage . . .	None original	Distinct basal
Sp. gr. . . .	3·902	4·364
Refractive indices .	ω 1·6742	1·569
	ϵ 1·7701	1·670
Crystal-system .	Rhombohedral	Hexagonal

In general appearance and in some other respects the two minerals are, however, very similar, and the crystal-forms of synchysite can be referred to the axes of parisite. L. J. S.

Selenium Minerals from the Skrickerum mine, Sweden (E. Svedmark, Teknisk Tidskrift, 1899; abstract in Zeits. Kryst. Min., 1901, vol. xxxiv, p. 693).—The Skrickerum mine in the parish of Tryserum, government Kalmar, Sweden, is noted for the selenium minerals, eucairite (CuAgSe), berzelianite (Cu_2Se), and crookesite ($(Cu,Tl,Ag)_2Se$), which it has yielded, and it was from here that Berzelius in 1818 described the first mineral found to contain this element. The mine was worked only from 1779 to 1784 for copper ores, and all the previous mineral finds were made on the old heaps of mine refuse. Recently (1898) the mine has been opened up again, by a party of mineral collectors, for the rare selenium minerals, which occur in a small calcite vein. The berzelianite is present as a dusty impregnation in the calcite, and varies in amount from a trace to ten per cent., averaging about three per cent. of the whole mass. Eucairite, as silver-white to blue-grey, malleable grains, is of rarer occurrence. Associated minerals are:—native silver and copper, cuprite, several iron silicates, carbonaceous pitchblende, uranium ochre, &c.

L. J. S.

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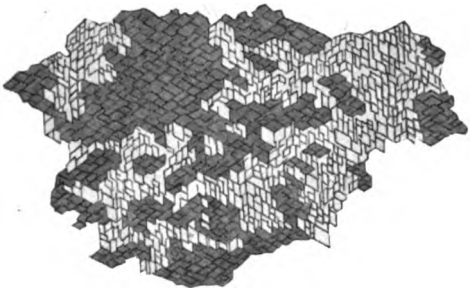

Fig. 1.

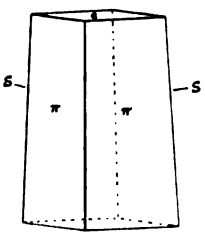

Fig. 2.

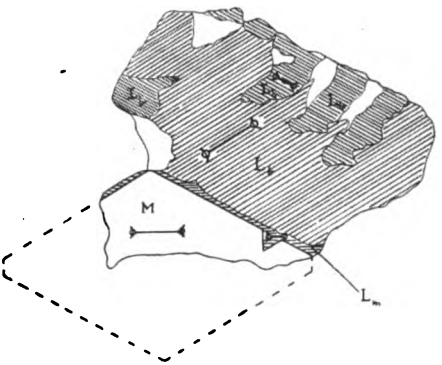

Fig. 3.

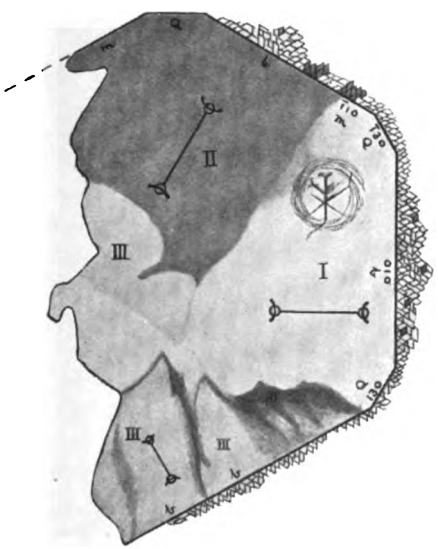

Fig. 5.

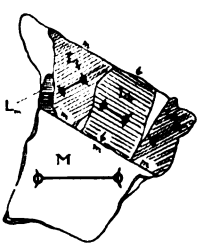

Fig. 4.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF

THE MINERALOGICAL SOCIETY.

No. 61. FEBRUARY, 1903. Vol. XIII.

The Chemical Composition and Optical Characters of Chalybite from Cornwall.

By A. HUTCHINSON, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Read April 3, 1900.]

THE acquisition by the Cambridge Mineralogical Museum of a series of well-crystallized specimens of chalybite, raised within recent years from the mines in the neighbourhood of Camborne in Cornwall, afforded a favourable opportunity for an investigation of the chemical composition and optical characters of this substance. This seemed the more desirable since no analysis of the chalybite crystals from the Camborne district appears to have been published, and our knowledge of the optical characters of the substance is confined to some observations of Ortloff[1] on material containing large quantities of manganese carbonate from Wolfsberg in the Harz.

The specimen examined by Ortloff was of a pale yellow colour and had a cleavage angle of 72° 55′. Its composition was as follows:— $FeCO_3$, 77·32; $MnCO_3$, 17·04; $MgCO_3$, 5·42; $CaCO_3$, 0·86; total, 100·64. The refractive indices for D light, determined by means of

[1] Zeits. Phys. Chem., 1896, vol. xix, p. 215.

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a prism of which the orientation is not stated, were: $\mu_o = 1{\cdot}93409$, $\mu_e = 1{\cdot}62185$.

The crystals used in the experiments described below were essentially combinations of the basal plane with a rhombohedron, and somewhat resembled octahedra in appearance[1]. The crystals measured from 5 to 10 mm. along the edges of the basal plane and were implanted on quartz. The faces were rough and uneven and did not lend themselves to a determination of the forms present.

On breaking up the crystals they yielded perfectly transparent cleavage fragments of a pale yellow colour. Some of the larger crystals were selected for the purpose of making into prisms, and from the remainder some 7 grams of pure fragments were obtained, and these were submitted to chemical analysis after determinations of the cleavage angle and specific gravity had been made.

Angle between the cleavage planes.—This was found to vary somewhat in the larger crystals, but a number of small fragments which gave good reflections yielded values lying between 73° 5′ and 73° 0½′. Mean value 73° 2½′.

Specific Gravity.—The specific gravity was determined by the aid of a pycnometer which contained 9·9782 grams of water at 17·7°C. Corrections were applied for weighing in air and for the temperature of the water. Two independent determinations made on the same sample gave the following results:—

Sp. gr. at 16·9°/4° = 3·938. (Weight of chalybite used, 5·6336 grams.)
„ „ 17·1°/4° = 3·936. („ „ 5·6207 „)

Chemical Analysis.—The mineral was completely soluble in hydrochloric acid. After oxidation, the iron and manganese were separated by a double precipitation with ammonium acetate. As traces of calcium and magnesium were found in the filtrate after the separation of the manganese, a special determination of these constituents was made. For this purpose iron and manganese were removed by precipitation as sulphides, the filtrate was evaporated to dryness in a platinum dish, ammonium salts were removed by ignition, and the calcium and magnesium estimated in the minute residue. One determination of carbon dioxide was made; it agreed very closely with the amount required to combine with the oxides.

[1] Compare fig. 3, p. 276, of Dana's 'System of Mineralogy,' 6th edit., 1892.

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The results are exhibited in the following table:—

TABLE I.

	I.	II.	III.	IV.	V.
FeO	61·15	61·02	—	—	61·08
MnO	1·12	1·13	—	—	1·12
CaO	0·10	0·12	0·09	—	0·10
MgO	—	0·14	0·11	—	0·13
CO_2	—	—	—	38·19	38·19
					100·62

I. Weight of substance taken, 1·2027 gram. The iron and manganese were separated by ammonium acetate, the calcium precipitated as oxalate, and the presence of magnesium proved qualitatively in the filtrate.

II. Weight of substance taken, 0·9608 gram. The iron and manganese were separated as sulphides from the calcium and magnesium.

III. Weight of substance taken, 1·0978 gram. Calcium and magnesium alone determined after removal of the iron and manganese as sulphides.

IV. Weight of substance taken, 1·0288 gram. Carbon dioxide determined by absorption in potash.

V. Mean result.

If the quantities of the respective carbonates are calculated from the mean percentages of the oxides we obtain:—

$FeCO_3$	98·43
$MnCO_3$	1·82
$CaCO_3$	0·18
$MgCO_3$	0·26
	100·69

From the above results it is clear that this chalybite is nearly pure ferrous carbonate.

Optical Characters.—As there was not at my disposal an apparatus for grinding faces on crystals in any desired direction, the prisms employed for finding the refractive indices were cut arbitrarily by hand, and the orientation of the faces subsequently determined by measuring the angles that they made with the cleavage planes. The substance is easily ground down on a glass plate with fine emery, and an excellent polish can be given to it by means of rouge.

The prisms were set in each case to give minimum deviation for the ordinary ray, the deviation of the extraordinary ray was then determined

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without altering the position of the prism, and finally the angle at which the light was incident on the first face of the prism was found. The measurements were made for lithium, sodium, and thallium light, incident on each of the two faces of the prism in turn.

Three prisms were prepared. The first (I) was cut with its refracting edge not far removed from parallelism with the optic axis, and its refracting angle was 42° 36½′. After a series of measurements had been made, this prism was re-ground and re-polished and its refracting angle reduced to 39° 13′. A new series of determinations was then made with this prism, which will be referred to in future as (I a). This prism was of a pale yellow colour, and its faces, though small, about 6 sq. mm. in area, were good and afforded perfect images of the slit. The second prism (II) was larger, the area of its faces being about 20 sq. mm.: it was made from very perfect material, and the faces were excellent. Its refracting angle was 53° 41′. The third prism (III), refracting angle 47° 45½′, was about the same size as the last, and made from equally good material, but the angle between the two cleavage planes used for finding the orientation of the artificial faces was abnormal, being 73° 48′ instead of 73° 2½′, and this discrepancy makes the true value of the principal extraordinary index as found by this prism a little uncertain.

Calling the prism faces P and S, and two of the cleavage planes R and R_1 respectively, the six angles between these four planes were measured. The values obtained for each prism are given in the following table:—

TABLE II.

Prism.	PS	PR	PR_1	SR	SR_1	RR_1
	° ′	° ′	° ′	° ′	° ′	° ′
I.	137 23½	65 58	120 6	131 52	93 24	106 59
I a.	140 47	63 26	119 13½	130 48	93 12	106 59
II.	126 19	80 33	125 49½	107 22	106 38½	73 3
III.	132 14½	176 0	77 5	51 41	69 3½	106 12

As the prisms were set to give the minimum deviation of the ordinary ray, the corresponding indices of refraction can be calculated from the formula $\mu_o = \dfrac{\sin \frac{A+D_o}{2}}{\sin \frac{A}{2}}$, where D_o is the deviation observed and A the refracting angle of the prism.

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The velocity of the extraordinary wave and the direction of its normal in the crystal can be found by the method used by Glazebrook [1] in his verification of the law of double refraction in Iceland-spar. Let ϕ and ψ be the angles of incidence and of emergence respectively, ϕ' and ψ' the corresponding angles made by the wave-normal inside the prism, D_e the angle of deviation, and A the angle of the prism. Then we have

$$\phi + \psi = D_e + A \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\phi' + \psi' = A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\tan \frac{\phi' - \psi'}{2} = \tan \frac{\phi' + \psi'}{2} \tan \frac{\phi - \psi}{2} \cot \frac{\phi + \psi}{2} \quad . \quad (3)$$

From these formulae, since D_e, A, and ϕ are known, ϕ' and ψ' can be calculated.

If, now, V (= 1) is the velocity of light in air and v its velocity in the crystal, we have

$$\frac{V}{v} = \frac{\sin \phi}{\sin \phi'} = \frac{\sin \psi}{\sin \psi'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The velocities v were calculated in each case from ψ and ψ' as well as from ϕ and ϕ'; the values thus obtained agreed very closely, and the mean of the two was taken as the true value. The following table (III) gives the values of D_o, D_e, ϕ, and $\frac{1}{v}$ for each prism.

From a knowledge of the angles made by the prism faces with the cleavage planes (Table II) we can calculate the angle between the optic axis and the wave-normal to which the velocity v corresponds. Then if v_o and v_e be the two principal wave-velocities, we have

$$v^2 = v_o^2 \cos^2 \theta + v_e^2 \sin^2 \theta \quad . \quad . \quad . \quad . \quad . \quad (5)$$

whence the principal extraordinary index, μ_e, can be found.

The method of calculating the value of θ is illustrated by the accompanying stereogram [2], which represents the case of prism I. The faces of the crystal are referred to a rectangular axial system OX, OY, OZ, and the crystal is so placed that the edge between the two cleavage planes RR_1 is parallel to the axis OZ, while the angles between Rr_1 and RR_1 are bisected by X and Y respectively. P is the pole of one face of the prism, S the pole of the other, while s is the pole at the other end

[1] Phil. Trans. Roy. Soc., 1880, vol. clxxi, p. 421.

[2] In the figure the faces P and S are slightly removed from their true position for the sake of clearness. In an accurate drawing K and L would lie very close together. OZ is normal to the paper at O.

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TABLE III.

Prism.		Light incident on P.			Light incident on S.		
		Li.	Na.	Tl.	Li.	Na.	Tl.
I.	D_o	42° 41½′	43° 10½′	43° 35½′	42° 42½′	43° 11½′	43° 37′
	D_e	30 7	30 19½	30 32	30 9½	30 19½	30 32½
	ϕ	35 7	35 7	35 7	36 12	36 12	36 12
	$\frac{1}{v}$	1·6316	1·6356	1·6395	1·6328	1·6359	1·6401
I a.	D_o	38° 18′	38° 41½′	39° 4½′	38° 18′	38° 41′	39° 4½′
	D_e	27 28	27 38	27 47½	27 38	27 47	27 56½
	ϕ	38 47	38 47	38 47	40 1	40 1	40 1
	$\frac{1}{v}$	1·6326	1·6364	1·6399	1·6337	1·6371	1·6337
II.	D_o	60° 58½′	61° 45½′	62° 30′	60° 58½′	61° 45′	62° 28½′
	D_e	45 50	46 8	46 25½	44 45	45 5	45 21½
	ϕ	57 19¾	57 19¾	57 19¾	57 54½	57 54½	57 54½
	$\frac{1}{v}$	1·6785	1·6827	1·6867	1·6613	1·6661	1·6700
III.	D_o	50° 14′	50° 48′	51° 20½′	50° 13½′	50° 48′	51° 20′
	D_e	39 25	39 41	39 57½	40 3½	40 21	40 37
	ϕ	48 48	48 48	48 48	49 40¾	49 40¾	49 40¾
	$\frac{1}{v}$	1·6977	1·7021	1·7066	1·7063	1·7111	1·7156

of the normal on S, hence Ps represents the internal prism angle A. One end of the optic axis emerges at T, and the angle ZT can be calculated from the cleavage angle RR_1. From the spherical triangles PRX, Pr_1X, the angle PX can be found, for we have

$$\cos PX = \frac{\cos \frac{PR+Pr_1}{2} \cos \frac{PR-Pr_1}{2}}{\cos \frac{Rr_1}{2}}.$$

Similarly, we can find PY, sX, and sY.

The angle sM can be found by the formula

$$\cot sM = \frac{\sin PK}{\sin sL \sin Ps} + \cot Ps,$$

for we know $PK = PY - 90°$, $sL = 90° - sY$, and $Ps = A$. From the right-angled spherical triangle sLM, in which we know sL and sM,

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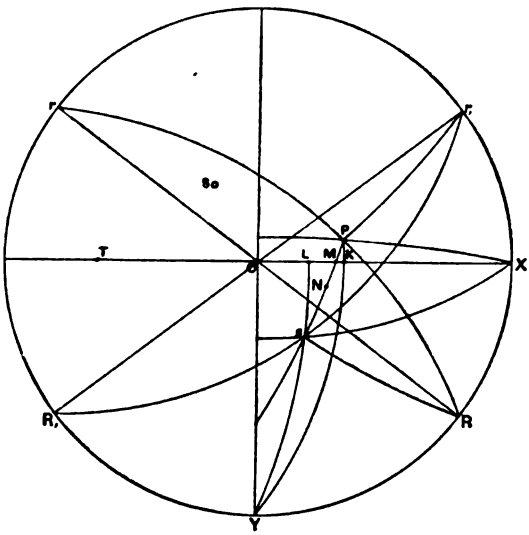
we can find LM and the angle LMs. Again, from the right-angled spherical triangle sLX we can find LX and so obtain the value of TM $= 90° - LX + LM + ZT$. The position of emergence in Ps of the wave-normal N is known, for we have determined the angles ϕ' and



ψ' which it makes with the normals to the prism faces. Hence from the spherical triangle TMN, in which the sides TM, MN, and the angle TMN are known, we can find the side TN $= \theta$, the angle between the wave-normal and the optic axis. The values calculated for θ are given in Table IV.

TABLE IV.

Prism.		Light incident on P.			Light incident on S.		
		Li.	Na.	Tl.	Li.	Na.	Tl.
		° ′	° ′	° ′	° ′	° ′	° ′
I.	θ	96 26½	96 27	96 27½	96 19½	96 19	96 18½
I a.	θ	95 43½	95 44	95 45	97 10	97 9½	97 8½
II.	θ	60 38½	60 42½	60 46½	66 21½	66 17	66 13
III.	θ	54 26½	54 24	54 22	51 58	52 0	52 2

The following table (V) contains the values of μ_o and of μ_e obtained from each prism according as the light was incident on P or on S.

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TABLE V.

Prism.	Light incident on face.	μ_o			μ_e		
		Li.	Na.	Tl.	Li.	Na.	Tl.
I.	P	1·8648	1·8733	1·8807	1·6291	1·6331	1·6370
	S	1·8651	1·8736	1·8811	1·6303	1·6335	1·6377
	Mean	1·8649	1·8734	1·8809	1·6297	1·6333	1·6373
I a.	P	1·8655	1·8734	1·8812	1·6306	1·6344	1·6379
	S	1·8655	1·8733	1·8812	1·6307	1·6340	1·6376
	Mean	1·8655	1·8733	1·8812	1·6306	1·6342	1·6377
II.	P	1·8643	1·8724	1·8801	1·6304	1·6340	1·6375
	S	1·8643	1·8723	1·8798	1·6295	1·6336	1·6368
	Mean	1·8643	1·8724	1·8799	1·6299	1·6338	1·6371
III.	P	1·8642	1·8722	1·8798	1·6281	1·6310	1·6344
	S	1·8641	1·8722	1·8797	1·6275	1·6310	1·6344
	Mean	1·8642	1·8722	1·8798	1·6278	1·6310	1·6344

It will be seen that the results exhibit a satisfactory degree of concordance; those yielded by prism II are probably nearest to the truth.

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Note on a connexion between the molecular volume and chemical composition of some crystallographically similar minerals.

By G. T. Prior, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read June 18, 1901, and November 18, 1902.]

THE molecular volumes of the members of an isomorphous group of minerals in general show an approach to equality. In other words, minerals having an analogous chemical composition show not only closely related crystalline forms, but have also approximately equal molecular volumes. Many years ago J. D. Dana[1] endeavoured to show that a simple relationship as regards molecular volume also subsisted in the case of various minerals which were closely related crystallographically, although unlike chemically. He concluded that in these cases the similarity in form depended solely on the relationship in molecular volume, and had nothing whatever to do with the chemical composition.

In the case of many of these minerals, however (more particularly those showing the closest crystallographic similarity), it is possible to discover a chemical relationship, although it is not one of so intimate a nature as that which connects the members of the ordinary isomorphous groups. This relationship depends on the fact that the chemical formulae of the minerals showing close crystallographic similarity and approximately equal molecular volumes are of the same form and contain approximately the same number of atoms, although they may not represent salts of the same acid or salts of metals having the same valencies. As examples of 'isomorphous' minerals of this kind we have the often-cited case of

Calcite, $CaCO_3$, (V = 37)[2],
Sodium nitrate, $NaNO_3$, (V = 40),

and of the felspars

Albite, $NaAlSi_3O_8$, (V = 100),
Anorthite, $CaAlAlSi_2O_8$, (V = 100).

[1] Amer. Journ. Sci., 1850, ser. 2, vol. ix, p. 220.
[2] V = molecular volume, i. e. molecular weight divided by the density.

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The Hamlinite-Beudantite-Jarosite Group.

In a previous note in this Magazine (1900, vol. xii, p. 253) the above kind of chemical relationship was shown to subsist in the case of the crystallographically similar minerals hamlinite, florencite, plumbogummite, svanbergite, and beudantite, and it was suggested that these minerals formed a natural group. Of this group the three first minerals are phosphates, and the last two double phosphates and sulphates. The group may be made more complete by the addition of five minerals which are wholly sulphates, viz. alunite, jarosite, utahite, and the two new minerals, recently described by Hillebrand and Penfield, natrojarosite and plumbojarosite[1].

In the following table are exhibited the chemical and crystallographic relations of this group of rhombohedral minerals[2]. The molecular volumes given in the last column show an approximation to equality, so that the group behaves in this respect like the more ordinary isomorphous groups.

	Formula.	rr'.	d.	V.
Hamlinite	$AlPO_4 . SrHPO_4 . Al_2(OH)_6$	87° 2′	1·1353	142
Florencite	$AlPO_4 . CePO_4 . Al_2(OH)_6$	88 56	1·1901	143
Svanbergite[3]	$AlPO_4 . SrSO_4 . Al_2(OH)_6$	89 25	1·2063	140
Beudantite	$Fe'''PO_4 . PbSO_4 . Fe_2(OH)_6$	88 42	1·1842	155
Alunite	$AlSO_4KSO_4 . Al_2(OH)_6$	90 50	1·2520	150
Jarosite	$Fe'''SO_4KSO_4 . Fe_2(OH)_6$	90 45	1·2492	154
Natrojarosite	$Fe'''SO_4NaSO_4 . Fe_2(OH)_6$	85 54	1·1038	154
Plumbojarosite	$Fe'''SO_4Pb\frac{1}{2}SO_4 . Fe_2(OH)_6$	89 42	1·2156	154
Utahite[4]	$Fe'''OHSO_4 . Fe'''OHSO_4 . Fe_2(OH)_6$	84 9	1·0576	—

Plumbojarosite, it must be confessed, stands a little out of the picture. The isomorphism of Pb and K_2 is certainly very unusual: it is considered by Penfield to be conditioned by the controlling influence or *mass effect* of the other constituents in the complex molecule. Whether 'mass effect' is to be appealed to or not as the cause of the close crystallographic relationship of the other members of the group, it is evident that in these minerals of complex chemical composition such a grouping

[1] Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 211; and Zeits. Kryst. Min., 1902, vol. xxxvi, p. 545.

[2] Plumbogummite is left out of account owing to the lack of crystallographic data.

[3] The presence of strontia with lime in the mineral from Horrsjöberg has been determined by testing in the same way as in the case of the Westanå mineral (see previous paper, l.c., p. 252).

[4] A. Arzruni and K. Thaddéeff, Zeits. Kryst. Min., 1899, vol. xxxi, pp. 234, 244.

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as $CePO_4$ can be replaced by $SrSO_4$, and $AlPO_4CePO_4$ by $AlSO_4KSO_4$, &c., without materially affecting the crystalline form. The formulae are written as above in order to make clear this chemical relationship. If doubled in order to show the isomorphism of K_2 and Pb, and written on the same plan as that adopted by Penfield, with hamlinite regarded as a pyrophosphate, they are as follows:—

Hamlinite . .	$[SrOH]_2[Al(OH)_2]_6[P_2O_7]_2$
Florencite . . .	$Ce_2[Al(OH)_2]_6[PO_4]_4$
Svanbergite . . .	$Sr_2[Al(OH)_2]_6[PO_4]_2[SO_4]_2$
Beudantite . . .	$Pb_2[Fe(OH)_2]_6[PO_4]_2[SO_4]_2$
Alunite . . .	$K_2[Al(OH)_2]_6[SO_4]_4$
Jarosite	$K_2[Fe(OH)_2]_6[SO_4]_4$
Natrojarosite . . .	$Na_2[Fe(OH)_2]_6[SO_4]_4$
Plumbojarosite . .	$Pb[Fe(OH)_2]_6[SO_4]_4$
Utahite . . .	$[Fe(OH)_2]_3[Fe(OH)_3]_6[SO_4]_4$

As further examples of similar relations connecting crystalline form, molecular volumes, and chemical composition may be mentioned the following groups of minerals.

	Formula.	System.	Elements.	V.
Monazite	$CePO_4$	Monoclinic	0·9693 : 1 : 0·9256; $\beta = 76° 20'$	47
Crocoite	$PbCrO_4$	,,	0·9608 : 1 : 0·9159; $\beta = 77° 33'$	54
Gypsum	$CaSO_4.2H_2O$	,,	0·6899 : 1 : 0·4124; $\beta = 80° 42'$	74
Brushite	$HCaPO_4.2H_2O$	,,	0·6221 : 1 : 0·3415; $\beta = 84° 45'$	78
Fergusonite	$YNbO_4$	Tetragonal (pyr. hemih.)	1 : 1·4643	47
Scheelite	$CaWO_4$	,,	1 : 1·5356	48
Chrysoberyl	$BeAlAlO_4$	Orthorhombic	0·4700 : 1 : 0·5800	36
Olivine	$MgMgSiO_4$	,,	0·4657 : 1 : 0·5865	44
Andalusite	Al_2SiO_5	,,	0·9861 : 1 : 0·7024	51
Olivenite	$Cu_2(OH)AsO_4$	,,	0·9396 : 1 : 0·6726	64
Diopside	$CaMgSi_2O_6$	Monoclinic	1·0921 : 1 : 0·5893; $\beta = 74° 10'$	66
Spodumene	$LiAlSi_2O_6$	,,	1·1238 : 1 : 0·6355; $\beta = 69° 40'$	60
Perofskite	$CaTiO_3$	Cubic	——	34
Bixbyite	$FeMnO_3$	,,	——	32
Geikielite	$MgTiO_3$	Rhombohedral	1 : 1·370 [1]	30
Ilmenite	$FeTiO_3$	,,	1 : 1·3846	32
Hematite	$FeFeO_3$	,,	1 : 1·3656	30

[1] P. von Sustschinsky, Zeits. Kryst. Min., 1902, vol. xxxvii, p. 57; abstract this vol., p. 307.

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In the preceding examples the chemical relationship of the minerals in each group is made evident by taking the ordinary formulae, and the molecular volumes which show an approximate equality are calculated from these formulae.

There are cases, however, of groups of two or more minerals which are very closely related crystallographically, but have molecular volumes far from equal when these are calculated from the ordinary formulae: these formulae, moreover, show no obvious relationships. In many of these cases it is found, in accordance with the principle which seems to hold good in the case of the preceding examples, that if in each group suitable multiples of the ordinary formulae of the minerals be taken so that the molecular volumes calculated from them are approximately equal, then these new formulae exhibit a similarity in form with approximately the same number of atoms.

This principle may supply a means in some cases of determining the simplest formulae of polymeric minerals, as in the following example of rutile, brookite, and anatase.

Formulae of Rutile, Brookite, and Anatase.

In the case of *rutile*, as an aid in the determination of its simplest chemical formula, we have its close crystallographic similarity with zircon.

For these two minerals the molecular volumes are:—

$$\text{Rutile } (TiO_2), \quad V = \frac{80}{4{\cdot}2} = 19.$$

$$\text{Zircon } (ZrSiO_4), \; V = \frac{182}{4{\cdot}7} = 39.$$

In order to bring these molecular volumes into approximate equality, that of rutile must be multiplied by 2.

The simplest formula, therefore, for rutile is Ti_2O_4 or $TiTiO_4$, which brings it into correspondence with that of zircon, $ZrSiO_4$.

In the case of *brookite*, its close crystallographic similarity with tantalite serves to suggest its formula.

The molecular volumes are:—

$$\text{Brookite } (TiO_2), \quad V = \frac{80}{4{\cdot}084}^{1} = 19{\cdot}6.$$

$$\text{Tantalite } (FeTa_2O_6), \; V = \frac{439}{8{\cdot}200}^{2} = 62{\cdot}32.$$

[1] Penfield's determination for brookite from Magnet Cove, Arkansas. Amer. Journ. Sci., 1886, ser. 3, vol. xxxi, p. 387.

[2] Headden's determination for tantalite from S. Dakota. Amer. Journ. Sci., 1891, ser. 3, vol. xli, p. 98.

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Here the molecular volume of brookite must be multiplied by 8, and the simplest formula for brookite is therefore Ti_3O_6 or $TiTi_2O_6$, to correspond with that of tantalite, $FeTa_2O_6$.

That these formulae, however, both of brookite and of tantalite, may have to be doubled is suggested by the well-known crystallographic relationship of these minerals with wolframite (hübnerite).

Thus for these three minerals the molecular volumes calculated from the simplest formulae are as follows:—

Brookite (TiO_2), $V = 19{\cdot}6$.

Tantalite ($FeTa_2O_6$), $V = 62{\cdot}32$.

Hübnerite ($MnWO_4$), $V = \frac{302{\cdot}4}{7{\cdot}177}$[1] $= 42{\cdot}133$.

In order to bring these molecular volumes into approximate equality, the simple formulae of the three minerals must be multiplied by 6, 2, and 8 respectively, when the chemical relationship becomes at once apparent.

The molecular volumes and topic axes of the three minerals are then as follows:—

	V	χ	ψ	ω
Brookite ($Ti_2Ti_3O_{12}$),	117·54	4·450	5·288	4·994
Tantalite ($Fe_2Ta_4O_{12}$),	124·64	4·581	5·530	4·920
Hübnerite ($Mn_3W_3O_{12}$),	126·40	4·647	5·599	4·859.

In the case of *anatase* (TiO_2, $V = 20$), its close crystallographic similarity with calomel (Hg_2Cl_2, $V = 72$) and matlockite (Pb_2Cl_2O, $V = 70$) suggests that Ti_4O_8 ($V = 80$) is the most probable formula, although here the dissimilarity between the chemical compounds renders the evidence less convincing than in the case of rutile and brookite.

The most probable simplest chemical formulae therefore for the three modifications of titanic acid are:—

Rutile . . .	Ti_2O_4.
Anatase . . .	Ti_4O_8.
Brookite . . .	Ti_6O_{12}.

This result is the same as that to which Schrauf[2] was led from the consideration of atomic groupings in accordance with the crystallographic symmetry.

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[1] Hillebrand's determination for hübnerite from Ouray Co., Colorado. Amer. Journ. Sci., 1884, ser. 3, vol. xxvii, p. 357.

[2] Zeits. Kryst. Min., 1884, vol. ix, p 488.

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The chemical and crystallographic relations and the molecular volumes of the above and other similar groups of minerals are exhibited in the following table:—

	Formula.	System.	Elements.	V.
Zircon	$ZrSiO_4$	Tetragonal	1 : 0·6404	89
Rutile	$TiTiO_4$	,,	1 : 0·6442	88
Sellaite	$MgMgF_4$	,,	1 : 0·6596	41
Xenotime	YPO_4	,,	1 : 0·6187	41
Brookite	$Ti_2Ti_4O_{12}$	Orthorhombic	0·8416 : 1 : 0·9444	118
Tantalite	$Fe_2Ta_4O_{12}$	,,	0·8285 : 1 : 0·8898	125
Hübnerite	$Mn_2MnW_2O_{12}$	Monoclinic	0·8300 : 1 : 0·8678; $\beta = 89° 22'$	126
Celestite	$SrSO_4$	Orthorhombic	0·7789 : 1 : 1·2800	47
Marcasite	$FeFeS_4$	,,	0·7662 : 1 : 1·2342	50
Copper-pyrites	$Cu_2Fe_2S_4$	Tetragonal	1 : 0·9853	88
Stannite	Cu_2FeSnS_4	,,	1 : 0·9827	95
Calcite	$Ca_2C_2O_6$	Rhombohedral	1 : 0·8543	74
Nordenskiöldine	$CaSnB_2O_6$	,,	1 : 0·8221	65
Calomel	Hg_2Cl_2	Tetragonal	1 : 1·7229	72
Matlockite	Pb_2Cl_2O	,,	1 : 1·7627	70
Anatase	Ti_4O_8	,,	1 : 1·7771	80

The principle enunciated in the present note of the approximate equality of molecular volumes corresponding to similarity in form of the chemical formulae in the case of minerals showing close crystallographic relations, although holding good for a large number of cases, is not of general application to compounds of any elements whatever. Thus the well-known homoeomorphous minerals zincite (ZnO), greenockite (CdS), and iodyrite (AgI), although having equal number of atoms in the molecule and showing the closest possible crystallographic relationship, have molecular volumes of 15, 30, and 40 respectively, which are certainly not equal, although, it may be pointed out, nearly in the simple ratio of 1 : 2 : 3. Further, the principle is not always a reversible one, for minerals having approximately equal molecular volumes and formulae similar in form may show no crystallographic similarity; e. g. neither scorodite, $FeAsO_4 . 2H_2O$ (V = 72), and gypsum, $CaSO_4 . 2H_2O$ (V = 74), nor pucherite, $BiVO_4$ (V = 53), and celestite, $SrSO_4$ (V = 47), show any close similarity in crystalline forms.

It would seem that, just as in an ordinary isomorphous group there are *single* elements which may be termed crystallographically equivalent, so in the case of the crystallographically similar minerals discussed in the

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present note there are *groups* of elements which are crystallographically equivalent. Thus, as regards their influence on molecular volume and the determination of crystalline form, it would appear from the preceding examples that

CaC	is equivalent to	NaN
NaSi	,,	CaAl
CeP	,,	PbCr
YNb	,,	CaW
Al_2Si	,,	Cu_2As
$BeAl_2$	,,	$SiMg_2$, &c.

In many cases, however, especially where the chemical molecule is a very complex one, the equivalence of certain groups may be only approximate, and the fact that they can replace each other in such complex minerals without appreciably affecting the crystalline form may depend to some extent on the 'mass effect' of the other constituents of the molecule, as suggested by Penfield.

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Serendibite, a new borosilicate from Ceylon.

By G. T. Prior, M.A., F.G.S., and A. K. Coomáraswámy, B.Sc., F.G.S., F.L.S.

[Read February 4, 1902.]

Mode of Occurrence.—This new mineral was discovered at Gangapitiya, near Ambakotte and about 12 miles east of Kandy, Ceylon. In this locality quarries have been dug for the well-known Ceylon moonstone, which occurs in large porphyritic crystals in an acid granulite.

Bands of this granulite, which is composed mainly of quartz and felspar in finely granulitic and occasionally graphic structure, alternate with bands of limestone up to 18 inches wide. Between limestone and granulite occur contact-zones consisting, next to the limestone, almost entirely of a colourless diopside, but near the granulite of a mixture of diopside with other minerals, viz. blue spinel, a little apatite, occasionally scapolite or plagioclase, and the blue mineral which is the subject of the present note. Hand-specimens may be collected showing this relation. The serendibite occurs in sufficiently large amount to give a deep blue colour to the contact-zones [1].

Physical Characters.—The association of the serendibite with the diopside and spinel is of such an intimate nature that no definite crystals could be isolated from the material at our disposal.

Examination of fragments of the mineral and of thin slices of the rock in which it occurs, shows that it is biaxial and probably anorthic. Besides the marked pleochroism, from very pale yellow (nearly colourless) to deep indigo-blue, the most notable feature to be observed in thin slices is the remarkable polysynthetic twinning, which is quite as intimate as that of a plagioclastic felspar.

The mineral occurs for the most part in irregular grains. In parts of the rock, however, radiating detached grains of the serendibite are seen

[1] Further details as to the mode of occurrence of the mineral will be found in Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 421.

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to belong to one individual crystal and to form a sort of ophitic structure with the diopside; while occasionally more definite crystals have been formed which show in thin slices traces of a prism or pinacoid, along which they are elongated and parallel to which occurs the twinning. Such crystals often show traces of two terminal faces. In the section of the crystal shown in the accompanying figure these terminal faces are inclined to each other at an angle of about 104°, and to the adjacent side planes at angles of about 138° and 122° respectively. In this crystal the extinction is nearly symmetrical and about 15° for the two sets of twin-lamellae, each of which shows the emergence of an optic axis nearly central: the pleochroism was from very pale yellow (nearly colourless) for vibrations parallel to the line of extinction to sky-blue at right-angles: compensation with the quartz-wedge took place at right-angles to the line of extinction.

Thin section of a crystal of serendibite between crossed nicols, one set of twin-lamellae being in the position of extinction. (Magnification about 12 diameters.)

As at present imperfectly determined (owing to the lack of crystals), the physical characters of serendibite are as follows:—

Biaxial, probably anorthic; polysynthetic twins with twin-plane probably a pinacoid; cleavage, none; fracture, subconchoidal; hardness, nearly that of quartz, $6\frac{3}{4}$; density, 3·42 (determined on 0·2710 gram); lustre, vitreous; colour, blue, varying in different varieties from pale sky-blue to deep indigo-blue; transparent; pleochroism, in one variety very pale yellow (almost colourless) to pale sky-blue, in another variety pale brownish-yellow to deep indigo-blue; refraction, near that of diopside, and between monobromonaphthalene and methylene iodide, about 1·7; double refraction, weak.

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Chemical Composition.—The mineral is infusible: it is only slightly attacked by acids, even hydrofluoric: heated in the closed tube, it gives a little water with doubtful traces of etching from fluorine: fused with calcium fluoride and acid sulphate of potash it imparts to the flame the green colour characteristic of boron. The presence of boron was confirmed by fusing the powdered mineral with sodium carbonate, extracting the melt with water, acidifying with acetic acid and distilling with methyl alcohol; the distillate was treated with lime to fix the boracic acid and evaporated to dryness; the residue, treated with sulphuric acid, imparted a green colour to the flame of methyl alcohol, and, dissolved in hydrochloric acid, gave the characteristic red colour to turmeric paper.

Material for analysis was carefully selected as follows. Fragments of the rock were crushed and the powder retained between sieves of 30 and 60 meshes to the inch; pure grains of serendibite were then picked out with a fine brush and examined, grain by grain, under the microscope and tested for pleochroism and double refraction. Of material picked out in this way only 0·3304 gram was available for the main analysis, and 0·2406 for the alkali determination. The amount of material at our disposal did not allow of a satisfactory direct determination of the boracic acid.

The result of the analysis (G.T.P.) is as follows:—

		Molecular ratios.	
SiO_2	25·33	0·42	
Al_2O_3	34·96	0·35	
FeO	4·17	0·06	0·69
CaO	14·56	0·26	
MgO	14·91	0·37	
Na_2O, Li_2O	0·51[1]		
K_2O	0·22		
Loss on ignition	0·69		
P_2O_5	0·48		
F	not determined		
B_2O_3 (by diff.)	(4·17)	0·07	
	100·00		

[1] Calculated as if wholly Na_2O: the presence of lithium, however, was clearly indicated by the spectroscope.

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A provisional formula is

$$10(Fe,Ca,Mg)O.5Al_2O_3.6SiO_2.B_2O_3.$$

This may be written

$$6(Fe,Ca,Mg)SiO_3.4MgAl_2O_4.2AlBO_3$$

suggestive of a combination of aluminium borate with molecules having the composition of diopside and spinel, the two minerals with which serendibite is so intimately associated. The mineral has some relationship with tourmaline in being a borosilicate of alumina, magnesia, and alkalies (including lithia). It has been formed as a contact mineral instead of tourmaline[1], probably owing to the basic conditions induced by the presence of the limestone. In many of its physical characters, colour, hardness, and density, the mineral is very similar to sapphirine.

It is hoped that more material (and especially crystals) may soon be available in order that the description of the mineral may be made more complete.

The name 'serendibite,' given to the mineral, is derived from 'Serendib,' an old Arab name for Ceylon.

[1] Tourmaline was also found very sparingly in the contact-zones, but the few crystals observed occurred only in soft material apparently filling cracks in the harder rock.

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Contributions to the Petrology of British East Africa.

Comparison of volcanic rocks from the Great Rift Valley with rocks from Pantelleria, the Canary Islands, Ascension, St. Helena, Aden, and Abyssinia. (With plate V.)

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[Read March 25 and November 18, 1902.]

THE following notes on the petrology of British East Africa are the result of an examination of rock-specimens collected by Professor J. W. Gregory on his well-known expedition from Mombasa to Mt. Kenya and Lake Baringo in 1892–3, and of rock-collections from the Uganda Protectorate which have been recently presented to the British Museum by Sir Harry Johnston.

The collections include examples of the Archaean gneisses, schists, and granites which constitute the prevailing basement rocks of Central Africa; of ferruginous schists, coarse sandstones, and quartzites belonging to the Palaeozoic Karagwe series; and of an interesting series of Tertiary volcanic rocks comprising phonolites, phonolitic trachytes, riebeckite-rhyolites, kenytes, and basalts from the volcanoes of the Great Rift Valley, as well as of nephelinites and basaltic rocks containing melilite and perofskite from Mt. Elgon.

GNEISSES, SCHISTS, GRANITES, AND GRANULITES.

These are the basement rocks which occupy such a prominent position in the geology of the African continent. As is well known, the general prevalence of these rocks in Central Africa led Murchison to the hypothesis that this region, like that of southern India, is one of great antiquity which has for the most part never been below the level of the sea.

According to Prof. Gregory[1], in a journey inland from Mombasa to Uganda, after the low-lying coast region with its fringe of coral-rock and Triassic sandstone has been traversed, gneisses and schists become the prevailing rocks until the region of the Great Rift Valley is approached, when they are covered by the enormous outpourings of

[1] The Great Rift Valley. London, 1896, p. 227.

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phonolitic lavas from Mt. Kenya and the volcanoes of the Rift Valley. On the western side of the valley, however, the Archaean rocks reappear in the Elgon District and Victoria Nyanza region, where they are in places covered by the ferruginous schists and sandstones of the Karagwe series: thence they extend across Uganda and constitute the main mass of Ruwenzori.

Of these rocks, specimens were collected by Prof. Gregory from the east side of the Rift Valley before the volcanic region was reached. In Sir Harry Johnston's collections from the Uganda Protectorate there are specimens of *gneiss* from the Central Province (Iganga, and the Kadudamu and Kamurujo Hills), Kavirondo (Kisumu), the Elgon District (Tindi, Marama, Ketosh, Kakumega, Nyala, Samia Hills), Unyoro, the Nile Province, and Ruwenzori; of *mica- and hornblende-schists* from the Central Province (Jinga, Nampirika, and the Nabutitisi Hills), Ankole (Egara Hills), Unyoro, Toro, and Ruwenzori; and *granites* from Toro (Katwe), Central Province (Iganga, Kakani Hill), Kavirondo (Awichina near Kisumu), and Samia Hills.

Gneisses and schists from tropical East Africa have been minutely described by Rosiwal [1], and gneisses and granulites from Massailand by Mügge [2] and by Lenk [3], so that only a few points on the microscopic examination of these rocks will be noted here.

Like many of those described by Rosiwal, the *gneisses* in the present collections are characterized for the most part by the large amount of microcline and by their granulitic structure. Some specimens of granite-gneiss from Unyoro, however, present rather the characters of crushed granites. They consist mainly of an aggregate of microcline and quartz with very little ferromagnesian mineral, and show under the microscope very pronounced cataclastic structure. A gneissic-looking rock from Diwona Camp, Ruwenzori [4], has the characters of a crushed and metamorphosed gabbro or coarse dolerite: it consists of large bent and distorted felspars showing microcline-like cross-hatchings, and large crystals of purple augite altered on the margin to hornblende and granular epidote: the interspaces between augites and felspars are occupied by a quartz-felspar-mosaic showing cataclastic structure.

In association with the gneisses and schists occur, both on the east of the Rift Valley and in Uganda, *granulites* similar to the well-known

[1] Beitr. z. geol. Kennt. d. östlichen Africa. Vienna, 1891.
[2] Neues Jahrb. Min., 1886, Beil.-Bd. iv, p. 516.
[3] Baumann, Durch Massailand zur Nilquelle. Berlin, 1894, p. 268.
[4] The specimen is from the Scott Elliot collection in the British Museum.

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series in India and Ceylon to which Mr. T. H. Holland has given the name of charnockite[1]. Thus from Unyoro (Chief Matwe) comes a specimen of typical hypersthene-granulite consisting of a granulitic aggregate of quartz and oligoclase, with strings of pleochroic (colourless to rose-red) hypersthene-grains and deep brownish-red biotite in large amounts. A specimen from Kikwen, Iveti Mts., is a kyanite-quartz-granulite in which grains of deep red rutile in large amount are included in both quartz and kyanite.

At Lugard Falls, on the Sabaki River, the granulites, which occur in intimate association with the gneisses, contain, besides biotite, also much pleochroic (brownish-yellow to deep bluish-green) hornblende, and in some cases also a pale bluish-green pyroxene (sahlite). By failure of biotite and increase in the amount of hornblende, these rocks pass into *amphibolites*. In some specimens red garnet is also present, and in this case the hornblende often occurs in peculiar blebs arranged in centric structure, and the garnet contains inclusions of the quartz-felspar-groundmass and also of the green hornblende. A specimen of *granulite* from five days west of Hamaye shows under the microscope (fig. 1, pl. V) pink garnets, in large crystals with very ragged outlines and also in curious vermicular blebs, in a granular base of large plates of oligoclase showing fine twin-striations: besides the garnet, but in smaller amount, occurs the same bluish-green hornblende as in the amphibolites in patches of small blebs, in part isolated in the felspar-base but mainly completely enclosed by the garnet. Plentifully scattered through the slide and enclosed in all the other constituents are minute colourless blebs of a strongly refractive (the refraction is higher than that of the garnet) and doubly refractive mineral which is referable with little doubt to sphene, since it shows a positive biaxial figure with dispersion $\rho > v$ and an optic axial angle equal to that shown by a specimen of sphene. Peculiar centric structures of pyroxene have been recently described by Mr. A. K. Coomáraswámy in garnet-granulites from Ceylon and are attributed by him to corrosion of the garnets by a felspathic magma[2]. In the present case, however, the appearances rather suggest the idea that the garnet has grown at the expense of the hornblende, and they thus tend to favour the views of Mr. T. H. Holland[3], who considers the garnets in many of the granulites of southern India as of secondary origin and derived from pyroxenes which are undergoing amphibolization.

[1] Mem. Geol. Survey India, 1900, vol. xxviii, part 2, pp. 119-249.
[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 601.
[3] Records Geol. Surv. India, 1896, vol. xxix, p. 20.

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A garnet-hornblende-granulite from Madagascar in the Museum collection presents characters almost identical with those of the present rock. The pink garnet and bluish-green hornblende are precisely similar, but the latter mineral occurs more plentifully in patches of small blebs in the felspar-base than enclosed in the garnets. However, some of the irregular grains of hornblende are enclosed in garnet, and in this case the contour of the latter mineral is seen to follow all the irregularities of the hornblende.

In Uganda the gneissic rocks appear to be traversed in many parts by veins both of acid pegmatites and of basic diabases (often converted into epidiorites). *Pegmatites* were found in Busoga (Iganga) and Bukedi (Kumaga and Kyabala), *diabases* at Kibui in Busoga and at Kabras in the Elgon District, and *epidiorites* on Ruwenzori, in Busoga (Iganga and Jinga), and in Unyoro.

Of crystalline *limestones* associated with the gneisses and schists, there is a specimen from the Bura Mts., Taita, which contains large crystals of a pale green diopside. Specimens in Sir Harry Johnston's collection, of earthy limestone from the Nyando Valley, Kavirondo, collected by Mr. C. W. Hobley from 'concretionary blocks in alluvial deposits overlying granite and gneiss,' are without doubt of recent origin.

FERRUGINOUS SCHISTS, SHALES, AND PHYLLITES; COARSE SANDSTONES AND QUARTZITES.

These rocks belong to the Palaeozoic Karagwe series of Scott Elliot and Gregory[1]. Rocks of this series are stated by them to occur on the Nandi Hills, where their superposition on the gneiss is clearly seen, on the Samia Hills in the Elgon District, and at Berkeley Bay on the east side of Lake Victoria Nyanza; while on the western side of that lake they extend over a distance of 100 miles from Butunguru on the Kagera River to Kiarutanga. The order of succession of the rocks belonging to this Karagwe series is given as follows:—(1) at the base, phyllites and ferruginous shales; followed by (2) red and brown sandstones; (3) coarse schistose sandstones; and (4) white granular quartzites.

In Sir Harry Johnston's collections from Uganda are many examples of these rocks. A remarkable series of ferruginous schists, shales, and phyllites comes from Unyoro (Chiefs Byabaswezi, Tibansamba, Kiza and Basigala), but there are also many specimens in the collections from Ankole, Busoga (Bukonge, Kalanga, and Jinga), and the Buvuma Islands in Lake Victoria Nyanza.

[1] Quart. Journ. Geol. Soc., 1895, vol. li, pp. 677–9.

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The ferruginous schists and shales from Unyoro vary in colour from pale brown and purple to deep brick-red. Some are banded from deep-red to nearly colourless. Most of them are hard compact and siliceous rocks passing occasionally into black lydite, while others which are softer and more schistose graduate into ferruginous phyllites.

In these characters the rocks present striking similarities with Dr. F. H. Hatch's Hospital Hill series of the southern Transvaal [1], and also with rocks from the Ingwenyaberg, Swaziland, which have been described by Prof. T. Rupert Jones [2]. With specimens of both these series in the Museum collection the African rocks have been compared. The Hospital Hill series of ferruginous shales occurs in the neighbourhood of Johannesburg as part of the Cape system, with the auriferous Witwatersrand quartz-conglomerate immediately above it. The Swaziland ferruginous shales and argillites, which probably belong to the same series, occur in association with gold-bearing serpentine and talcose schists. Amongst the rocks from Unyoro are specimens of quartz presenting some points of resemblance with that of the auriferous Banket formation of the Transvaal, but no visible gold has been detected on any of the specimens from Uganda.

Altogether the similarity of these schists and shales from Unyoro with those of the Transvaal is sufficiently striking to suggest the correlation of a part at least of the Karagwe with the Hospital Hill series. In their geological position and characters these rocks are also similar to the Cuddapah series of slates and quartzites which occurs above the gneiss in southern India. The ferruginous slaty rocks through which phonolitic rocks have been erupted in the neighbourhood of Adowa and Axum, Abyssinia [3], possibly also belong to the same group.

The rocks of the Karagwe series in all probability belong to the same formations as the schists and sandstones in the neighbourhood of Lake Nyasa described by Bornhardt [4]. Thus the schistose rocks in the Kinga region to the NE. of Lake Nyasa (the Urschiefer (?) formation of Bornhardt) appear to be somewhat similar to the rocks from Unyoro, since they consist of micaceous phyllites and light violet-red and brownish-grey to black shales. That Bornhardt would include some of the Karagwe series in this formation is also clear from the fact that he states that similar

[1] Quart. Journ. Geol. Soc., 1898, vol. liv, pp. 73–99.

[2] Geol. Mag., 1899, vol. vi, p. 105; the particular rocks are marked T. B. in the sections.

[3] This Magazine, 1900, vol. xii, p. 255.

[4] Deutsch-Ost-Afrika. Band vii, Geologie, Berlin, 1900.

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schists are mentioned by Reichenbach as occurring in a zone from the south and west of Victoria Nyanza along the east coast of Tanganyika up to the neighbourhood of Nyasa. To the Cape system, however, Bornhardt only doubtfully refers certain conglomerates and coarse sandstones which rest unconformably upon the Urschiefer rocks. In the present collections there are no specimens which can be said with certainty to correspond to the coal-bearing shales to the east and NW. of Lake Nyasa which are described by Bornhardt[1] and correlated by him with the Karoo of South Africa and the Gondwana system of India. Mention, however, is made in Sir Harry Johnston's description of Mt. Elgon[2] of rocks looking like sandstones and of coal-dust thickly strewn over pebbles in the stream-valleys, but no specimens are in the collection.

Of sandstones and quartzites belonging to the Karagwe series in the collections there are specimens from Bukonge on the north shore of Lake Victoria Nyanza (coarse ferruginous sandstone and white quartzite), Nakalanga in Busoga (colourless to pale purple sandstone), the Bugaya Islands, Kisubi and Tagana on the NW. borders of Lake Victoria Nyanza (ferruginous sandstones and quartzites), Ankole, and Unyoro. A white, fine-grained sandstone was also found on the east coast of Lake Naivasha at a height of 6,000 feet.

ERUPTIVE ROCKS.

The eruptive rocks connected with the Great Rift Valley cover an enormous extent of country, and are in this respect, as stated by Prof. Gregory, almost comparable with the Deccan traps of India or the Idaho basalts of North America. They were encountered by Prof. Gregory in his journey from Mombasa to Mt. Kenya soon after passing Mackakos. The immense plain extending westward at the foot of the old gneissic hills consisted of an enormous lava-flow which 'ended abruptly against the flank of the old gneiss ridge on its margin, but ran up the valleys and into the hollows of the mountains, just as the water of a lake follows the irregularities of its shore.'

This lava-region extends to the north, along the Rift Valley with its numerous craters, beyond Mt. Kenya and Lake Baringo, to the south beyond Mt. Kilimandjaro, and to the west across the Rift Valley and beyond the Mau escarpment to within a few miles of the east shore of Lake Victoria Nyanza (to Korando Hill and Kisumu).

The lavas are for the most part of a phonolitic type, rich in alkalies

[1] Loc. cit., p. 461.

[2] Geogr. Journ., 1902, vol. xix, p. 14.

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and poor in lime and magnesia, but forming a rock-series varying in basicity from basic kenytes and nepheline-rich phonolites through phonolitic trachytes to acid soda-rhyolites rich in quartz. The first eruptions which gave rise to the phonolitic lavas of the Kapte Plain are stated by Gregory to have taken place in Cretaceous times; in the later eruptions of Kamasia and Laikipia, basalts are associated with the phonolitic rocks; and in the still later eruptions of Kibo (Kilimandjaro) and of the neighbouring still active volcano of Doenyo Ngai, basic kenytes and nepheline-bearing basaltic rocks appear to be the prevailing lavas.

To this later period of eruption also belong the lavas of Mt. Elgon and the Nandi District on the western side of the Rift Valley. These consist mainly of nephelinites with melilite and perofskite, somewhat similar to the 'melilite-basalts' of Doenyo Ngai described by Mügge[1], and of Makinga Hill in German South-East Africa described by Lenk[2].

Further to the west across the Central Province of the Uganda Protectorate no volcanic rocks occur until the second line of weakness marked by the line of lakes from Tanganyika to Albert Nyanza is approached. Here at the foot of Ruwenzori (which itself consists of a block of Archæan gneisses and schists cut by dykes of epidiorite) occur numerous crater-lakes with masses of volcanic tuff, and nephelinites with perofskite are again met with, suggesting that these eruptions belong to the same period as those of Mt. Elgon and Doenyo Ngai.

Further south in NW. Ankole numerous crater-lakes with tuffs occur in the neighbourhood of Lake Albert Edward Nyanza. A specimen of tuff from this district is in the collection, and a scoriaceous olivine-basalt comes from one of the volcanic mountains between that lake and Lake Kivu.

For purposes of description the eruptive rocks will be taken in the following order:—

I. The Phonolitic Series, including:—
  (i) Phonolites, phonolitic trachytes, and phonolitic quartz-trachytes.
  (ii) Riebeckite-rhyolites (comendites) and other soda-rhyolites.
  (iii) Glassy equivalents of phonolites and soda-rhyolites.
  (iv) Kenytes ('trachydolerites').

II. Basalts.

III. Nephelinites containing melilite and perofskite, borolanite, &c., from Mt. Elgon, the Nandi District, and the foot of Ruwenzori.

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 595.

[2] Lenk, Ueber Gesteine aus Deutsch-Ostafrika; in Baumann, Durch Massailand zur Nilquelle, Berlin, 1894, p. 289.

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I. The Phonolitic Series.

These rocks are especially characterized by the amount and variety of soda-amphiboles (cossyrite, catophorite, arfvedsonite) as well as of soda-pyroxenes (aegirine and aegirine-augite), and (with the exception of the more ordinary type of phonolite in the Nandi District on the western side of the Rift Valley) by the absence of sphene and nosean, and also of magnetite except as inclusions in the augite-phenocrysts. The prevailing felspar is anorthoclase. They are thus closely related to the 'apachites' of Osann[1]. Almost exactly identical types, as shown later, are also presented by phonolitic rocks from the Canary Islands, the Azores, and the island of Pantelleria. Closely related trachytic rocks from Massailand, German East Africa, have been described by Mügge and by Lenk[2].

The rocks present a very striking example of a *rock-series*, showing the same gradation in character from rocks rich in nepheline at one end of the series to rocks rich in quartz at the other, as, e. g., in Brögger's grorudite-tinguaite series in the Christiania district, and in the similar series from Abyssinia described in a previous paper[3]. Mineralogically the whole group (with the exception of the more glassy rocks) is characterized by the presence of anorthoclase-felspar, and either soda-amphiboles or soda-pyroxenes or both, while in the phonolites at the basic end of the series there occurs, in addition, nepheline, and in the soda-rhyolites at the other end, quartz in large amount. Chemically the series is characterized throughout by the large amount of alkalies (especially of soda) and of iron and by the poverty in lime and magnesia. As seen in the analyses given on p. 247, the percentage of alkalies is fairly constant throughout, so that the individual rocks mainly differ in the relative amounts of the silica, alumina, and oxides of iron.

The following brief description of the more important *mineral-constituents* and their mode of occurrence applies mainly to the phonolites and phonolitic trachytes.

The *felspar*-phenocrysts are not very plentiful in these rocks. They consist mainly of clear glassy sanidines in long Carlsbad-twins showing the characteristic parting, and of anorthoclase recognizable by the minute twin-striations or mottled extinction. The larger crystals have peripheral bands of dark inclusions, and many are much corroded and partially

[1] Tschermak's Min. Mitth., 1896, vol. xv, p. 394.
[2] Loc. cit., p. 229.
[3] This Magazine, 1900, vol. xii, p. 255.

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reabsorbed, in which case they often have marginal bands of aegirine-grains. The felspar-laths of the groundmass probably belong to the same species: the larger ones are in Carlsbad-twins, some giving simultaneous straight extinction in the two halves, and others showing mottled extinctions suggestive of anorthoclase.

The *nepheline*-phenocrysts are generally in sharply defined rectangular and hexagonal sections with the cleavage in some cases well marked. They often contain inclusions of augite.

Of the pyroxene group, three members are generally present, viz. a pale green diopside-like augite, aegirine-augite, and aegirine.

The pale green *augite* occurs both as small phenocrysts and as irregular grains in the groundmass. The phenocrysts usually have a margin of grass-green aegirine and often contain inclusions of large magnetite grains and also needles of apatite. They are slightly pleochroic from yellowish-green to pale green, and the extinction is as high as 43°.

The pleochroic (grass-green to yellow) *aegirine*, except as a border round the augite-phenocrysts, only occurs in needles and ragged patches in the groundmass.

The *aegirine-augite* occurs in the same way as the aegirine, from which it is distinguished by its high angle of extinction and less brilliant colour.

Of the soda-amphiboles there are many varieties present in these rocks. They occur for the most part, like the soda-pyroxenes, in ragged patches in the groundmass.

Two varieties may be referred to the *catophorite* of Brögger. One of these (α) shows pleochroism similar to that of the Lougenthal mineral, viz.

$\mathfrak{a}$ = pale brownish-yellow to colourless,
$\mathfrak{b}$ = smoky brownish rose-red,
$\mathfrak{c}$ = reddish-yellow.

Sections with traces of two cleavages inclined at an angle of about 124° showed an optic axis on the edge of the field, while prismatic sections gave extinctions up to 40°: in a prismatic section with extinction of 25° to the cleavage, compensation took place with the quartz-wedge at right-angles to the line of extinction.

The other variety (β) of catophorite showed an approach to ordinary hornblende. The pleochroism was from pale smoky brownish-yellow with a tinge of green to deep purplish-brown nearly opaque. Extinction was as high as 23° and compensation took place at right-angles to it.

The mineral referred to *cossyrite* occurs in ragged ophitic patches

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and moss-like groups such as are characteristic of riebeckite. The pleochroism was $c > b > a$, with

a = smoky reddish-brown,
b = reddish-brown,
c = deep red-brown to opaque.

The extinction was as high as 43°.

In some specimens, besides the cossyrite and catophorite, occur patches of an *arfvedsonite*-like hornblende with pleochroism from pale smoky brown to pale lavender.

In the Kamasia phonolites occur also large moss-like patches of an amphibole near to *riebeckite* with pleochroism from pale brownish-yellow to a beautiful sky-blue (see fig. 4, pl. V). The riebeckite of the comendites presents the usual pleochroism and optical characters (p. 243).

Mica (*biotite*) occurs in very few specimens and then in only very small amount. It is generally partly reabsorbed and surrounded by an altered zone containing magnetite-grains and either aegirine or catophorite; occasionally it occurs as inclusions in the felspar- and nepheline-phenocrysts.

(i) *Phonolites and Phonolitic Trachytes.*

For purposes of description these rocks may be divided into five groups which graduate into each other:—

(*a*) Phonolites with nepheline in large phenocrysts.
(*b*) Phonolites with nepheline in small crystals surrounded by aegirine.
(*c*) Phonolites with nepheline in small crystals in the groundmass.
(*d*) Phonolitic trachytes with no recognizable nepheline.
(*e*) Phonolitic quartz-trachytes approaching soda-rhyolites.

(*a*) *Phonolites with Nepheline in large phenocrysts.*

In the rocks of this group phenocrysts, in small amount, of anorthoclase, sanidine, and nepheline, together with a little pale green augite, occur in a fine-grained felspar-nepheline groundmass scattered through which are ragged shreds and patches of aegirine, aegirine-augite, pale green augite, and the soda-amphiboles, dark, nearly opaque, reddish-brown cossyrite, and smoky rose-red catophorite. In this group lath-shaped felspar-microliths in the groundmass are not in large amount and flow-structure is not well marked. In the base there is generally some isotropic material (sodalite? or altered nepheline?) interspersed between the felspar-microliths, but nepheline in minute crystals is only rarely recognizable.

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Four types will be described, the three first of which differ for the most part only in the mode of aggregation of the soda-amphiboles and pyroxenes, while the fourth differs from the others in containing much sphene and no soda-amphiboles.

In the first type, which may be termed the *Losuguta type*, cossyrite and catophorite are scattered in grains and small patches very uniformly through the groundmass (see fig. 2, pl. V, in which is represented a portion of the groundmass as seen under a $\frac{1}{4}$ in. objective). In most of these rocks the felspar-microliths give some idea of definite flow-structure.

Of this type are specimens from the scarp of Lake Losuguta (291–3, and 301)[1], the summit and base of Doenyo lol Mwaru (421, 424), from north of Guaso Laschau in Laikipia (433), and from south of Lari lol Morjo (429).

In a second type, intermediate between the Losuguta type and the following one, the nepheline-phenocrysts are very large and the coloured constituents occur in more tuft-like feathery forms with intervening clearer spaces. The tufts consist mainly of cossyrite and aegirine or aegirine-augite (fig. 3, pl. V), but catophorite also occurs prominently in some specimens (427), and occasionally pleochroic (pale smoky brown to lavender or sky-blue) arfvedsonite-like hornblendes take the place to a large extent of aegirine. In this type the felspar-microliths have in places a certain directional character, but there is no definite line of flow.

Specimens of this type come from Doenyo lol Mwaru (423), from south of Lari lol Morjo (430), from bottom of ravine between Gopo lol Mwaru and Alngaria (427), from north of Guaso Narok (432), and from Korando Hill and Kisumu in Kavirondo.

In the third type, which may be termed the *Kamasia type*, the tufty patches of grass-green aegirine, deep red to black cossyrite, and sky-blue riebeckite-like amphibole (p. 237) reach their highest development and present a very remarkable appearance in thin sections under the microscope (fig. 4, pl. V). These rounded patches of soda-pyroxenes and amphiboles are scattered porphyritically through the groundmass together with phenocrysts of felspar and nepheline, leaving large spaces free from coloured minerals. They occur almost like a pigment, without crystal-outlines, around groups of minute rectangular nephelines which occasionally are altered to calcite, and also about the phenocrysts of felspar

[1] The numbers in parentheses refer to the specimens in Professor Gregory's collection. Most of the localities of these specimens are given in the maps, illustrating Professor Gregory's journey, in 'The Great Rift Valley.' London, 1896.

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and nepheline. In some specimens (385–6) the groundmass in which these patches occur consists mainly of felspar-microliths showing well-marked flow-structure, but in others (358) it is more crypto-crystalline and shows no flow-structure.

To this type belong specimens (385–6) from the foothills of Kamasia, and from gravel below basalt on the Kamnye River (358).

From the Nandi District on the western side of the Rift Valley comes a more ordinary type of phonolite with abundant sphene and no soda-amphiboles. A typical example is a specimen from the Sigowet Hills. This is a dark grey basaltic-looking rock showing to the naked eye large phenocrysts of nepheline with some augite and sphene. Under the microscope are seen large well-defined phenocrysts of nepheline, aegirine-augite, sphene, and a little nosean. The nephelines are generally remarkably free from inclusions, but sometimes contain a little aegirine-augite and sphene; the aegirine-augites show zonal structure with nearly colourless centres having a larger angle of extinction, and have generally a fringe of small grass-green aegirines: the sphene is in large twinned crystals, and the nosean shows inclusions of augite and sphene. The groundmass is to a large extent without action on polarized light, but contains felspar-laths and shreds of aegirine and small crystals of aegirine-augite bordered by aegirine.

Specimens from the bed of the Lower Kedowa River and the bed of the Seget River show almost precisely similar characters.

A dark grey basaltic-looking phonolite from Mt. Manava, Kavirondo, is of a more glassy type. In a glassy base, which is rendered dense with minute tufts of incipient aegirine (?), occur large nepheline-phenocrysts containing zonally arranged inclusions of augite and sphene: there are also small phenocrysts of a pale-green augite (with inclusions of magnetite), and of sphene.

(*b*) *Phonolites with Nepheline in small crystals surrounded by Aegirine* (*Kenya type*).

The type-rock of this group is the phonolite from Mt. Kenya which is figured by Professor Gregory [1]. The mineral constituents are the same as in the preceding group. The phenocrysts, however, consist mainly of felspar, and the groundmass is of coarser grain, the felspar-microliths and altered nephelines being replaced by a trachytic mesh of well-defined felspar-laths showing flow-structure. Scattered through the groundmass are small crystals of nepheline surrounded by ragged aegirine, while

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 210, pl. XI, fig. 5, and pl. XII, fig. 1.

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interspersed between the felspar-laths are grains and tufts of aegirine with cossyrite and in smaller amount catophorite. The felspar-phenocrysts are mainly of anorthoclase in Carlsbad-twins showing fine twin-striations; they have generally a narrow, strongly marked band of dark dusty inclusions just within the margin.

The rocks of this group are very similar to some of the phonolites of the Canary Islands which also contain cossyrite and catophorite. They would appear also to be absolutely identical with the 'acmite-trachytes' from Massailand described by Mügge[1], were it not for the fact that they contain nepheline in place of sodalite. In many of the specimens indeed the nepheline is much altered and isotropic and thus simulates sodalite, but in others it is perfectly fresh and doubly refracting, while hexagonal sections show well-defined negative uniaxial figures.

A quantitative analysis of the type-rock from the lava-flow at the base of Mt. Höhnel on Mt. Kenya, gave the following result (I) as compared with that of a somewhat similar phonolitic rock ('tinguaite') from near Axum, Abyssinia[2] (II).

	I. Mt. Kenya.	II. Axum.
SiO_2	58·37	57·81
TiO_2	0·21	—
Al_2O_3	16·65	18·74
Fe_2O_3	4·09	5·76
FeO	3·03	0·42
MnO	0·43	—
CaO	1·66	1·28
MgO	0·37	trace.
Na_2O	7·28	9·35
K_2O	5·46	4·52
P_2O_5	0·08	—
H_2O (below 110°)	0·96	—
H_2O (above 110°)	1·40	1·50
	99·99	99·38

Specimens belonging to this group come from the Athi Plain (166), from a hill below Fort Smith, Kikuyu (158), from the NW. side of the second swamp, Kikuyu (174), from the bed of a stream south of Guaso Laschau (438), and from the east of Losuguta Scarp (281, 284).

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 590.

[2] This Magazine, 1900, vol. xii, p. 269.

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(*c*) *Phonolites with Nepheline in the groundmass.*

In this group the felspar-phenocrysts are in small amount. Nepheline only occurs in the groundmass interspersed between the felspar-laths. Cossyrite and catophorite with aegirine and augite in varying relative amounts occur in ragged shreds and grains interpenetrated by the felspar-laths. The cossyrite is sometimes aggregated in minute tufts round the felspar-laths like iron-filings round a magnet. In some specimens clear isotropic patches (sodalite?) are present in small amount.

To this group belong specimens from Fort Smith in Kikuyu (160), from the plain at the foot of Doenyo Lersubugo (320), from the lava-capped plateau of Yatta to the east of Lugard's Falls (850), from the plateau above the south end of Lake Losuguta (296), from the Losuguta Scarp (275 and 285), from the Athi Plains (163), from the north end of the ridge west of Lake Kibibi (273), and from the steppes of the Kiroruma and Maranga (552).

(*d*) *Phonolitic Trachytes.*

These rocks present similar characters to those of the preceding phonolites in containing porphyritic anorthoclases and sanidines in a trachytic groundmass of felspar-laths with interstitial soda-pyroxenes and soda-amphiboles, but no recognizable nepheline is present.

Of these rocks one type is distinguished by the very strongly marked flow-structure of the felspar-laths, and by the scarcity of phenocrysts. A specimen from near Lake Baringo (311) presents a very striking appearance in section under the microscope, as it consists of a trachytic mesh of felspar-laths with a well-marked line of flow, and lenticular patches, almost continuous throughout the slide, of grass-green aegirine, nearly opaque cossyrite, and red ferrite (possibly pseudomorphous after a soda-amphibole).

Of another type nearer to that of ordinary trachytes are two specimens from Kamasia (357 from gravel below the basalt of Kamnye River, and 365 from the Mkuyuni River). They show a trachytic mesh of fairly large felspar-laths (mainly anorthoclase showing fine twin-striations) between which are interspersed irregular grains of pale-green augite, aegirine, and only a little cossyrite.

The rocks of this group are very similar to the so-called 'acmite-trachyte' of the Azores and of Kühlsbrunnen, Siebengebirge. They are also closely related to some of the more holocrystalline rocks described later (p. 247) under kenytes.

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(e) *Phonolitic Quartz-Trachytes.*

These rocks show fairly large phenocrysts of felspar (mainly anorthoclase in Carlsbad-twins) and, very sparingly, small green augites, in a mesh of felspar-laths micropoecilitic in a paste of quartz which depolarizes in patches. Uniformly distributed through the slide in large amount are ragged shreds of aegirine-augite, a little cossyrite, and much catophorite of the second variety (β). Characteristic of these rocks is the mode of occurrence of the quartz, not in phenocrysts but in micropoecilitic patches, forming a paste for the felspar-laths.

Precisely similar characters are presented by rocks from Punta Pozzolana, Pantelleria.

In this group are included specimens from Kikuyu Scarp (184, 194, 195), Kedong Scarp (182), Longonot (223), Equator Ridge (267), and Kirianduri (257).

(ii) *Riebeckite-Rhyolites (Comendites) and other Soda-Rhyolites.*

From Gilgil, north of Lake Naivasha, come some remarkable rocks characterized by their large contents of riebeckite and quartz. They appear to represent the volcanic equivalents of hypabyssal paisanites, and to form the most acid differentiation product of the soda-rich magma which has given birth to the flows of phonolitic lavas of the Rift Valley. In these rocks the pyroxenic minerals, green augite and aegirine, so characteristic of the phonolitic rocks, have been almost wholly replaced by the soda-amphibole, riebeckite. Examples of these rocks from Lake Naivasha have already been described by Mügge [1] and are included by Rosenbusch in the group of soda-rhyolites called 'comendites.'

The specimens in the collection made by Professor Gregory show some diversities in structure. A specimen (234) from south of Gilgil exhibits a pronounced flow-structure well marked by dense narrow bands, consisting mainly of riebeckite, alternating with clearer bands in which riebeckite has separated in small tufts and ragged needles, some of which project into cavities. The base consists of a micropoecilitic intergrowth of quartz and felspar, the clear quartz depolarizing in patches and forming a sort of paste in which are distributed clusters of felspar-microliths showing flow-structure. In this respect the base is thus somewhat similar to that of the phonolitic quartz-trachytes just described. The

[1] Neues Jahrb. Min., 1886, Beil.-Band iv, p. 596.

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riebeckite-needles show pleochroism from pale yellow for vibrations across their length (c-axis of indicatrix) to deep indigo-blue and almost opaque along the length (a): the extinction is nearly straight and compensation with the quartz-wedge takes place along the length. No porphyritic constituents are present and no definite glass can be seen.

A specimen from the centre of the lava-flow of Doenyo Buru, south of Gilgil, shows a similar quartz-felspar base, but here the riebeckite, instead of forming bands marking flow-structure, is very uniformly distributed in small ragged tufts and moss-like patches, and also in more definite crystalline grains in clearer quartz patches. From such grains, some of which showed the hornblende cleavage of about 124°, the pleochroism could be determined as

a = deep indigo-blue,
b = deep blue to opaque,
c = pale smoky yellow.

Besides the riebeckite, a little cossyrite was also present.

A rock (239) from a lava-flow below pumice, south of Gilgil, has somewhat different characters. It shows a similar quartz-felspar base, but no definite riebeckite occurs in the section, its place being taken, in small amount only, by aegirine and acmite (?) needles. The mineral here doubtfully referred to acmite occurs in small needles and radiating groups and also as an outer zone round aegirine-grains: it is strongly doubly refractive, compensates with the quartz-wedge along the length, and shows pleochroism:—a, along the length, reddish-orange; c, across the length, pale yellow.

A specimen (233) from a flow south of Gilgil is of coarser grain and porphyritic. It shows rounded and corroded phenocrysts of anorthoclase with some rounded crystals of pale green augite and rose-red catophorite, in a felspathic base containing some quartz.

The catophorite showed a hornblende cleavage of about 124° and had pleochroism:—

a = pinkish-yellow,
b = rose-red,
c = pale pinkish-brown.

The extinction was as high as 36° and compensation with the quartz-wedge took place at right-angles to it.

To this group of rocks may also be referred a specimen (225) from Kigate Crags, east of Longonot. It is, however, in parts much more coarse-grained and approaches in structure the paisanite from Mt. Scho-

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loda, Abyssinia, described and figured in a previous paper[1]. Large phenocrysts of clear Carlsbad-twins of sanidine and rounded quartz occur in large amount in a base varying in texture in different parts of the slide, but similar to that of the preceding rocks in consisting of a quartz-paste depolarizing in patches in which are distributed small prismatic felspars. Scattered uniformly through the slide in large amount are irregular grains and patches of riebeckite. A few phenocrysts of an altered brown hornblende with extinction (c-axis of indicatrix) of about 10° also occur and are generally surrounded by a border of projecting grains of riebeckite. Most of the felspar-phenocrysts are bordered by a zone of alteration marked by radiating felspar-laths and ferrite with riebeckite.

(iii) *Glassy equivalents of Phonolites and Soda-Rhyolites.*

The vitreous lavas vary considerably in chemical composition, for whereas some are the glassy equivalents of the phonolites and phonolitic trachytes, others are of a more acid type and have the composition of the soda-rhyolites or pantellerites.

Of phonolitic obsidians there are specimens from the rim of the crater of Longonot (222), the north face of Doenyo Nyuki (203), Losuguta Scarp (298), lake-terrace of Lake Suess (211), and Lake Nakuru. All of these show well-marked flow-structure.

The rock from Losuguta Scarp consists of a glassy base crowded with rounded dirty green patches of incipient aegirine, with here and there more definite aegirine-needles, and scattered felspar-microliths. It has characters somewhat similar to those of the rock from Lewis Col, Mt. Kenya, described by Professor Gregory[2], and also to those of rocks from Pantelleria.

Of more glassy character are the rocks from Longonot and Doenyo Nyuki. These are made up mainly of small deep brown spherulites showing well-marked black crosses between crossed nicols: a few needles of aegirine and one or two porphyritic anorthoclases are present. Phonolitic obsidians (so-called 'rhyolites') in the British Museum collection from the Vallée de Ucanca, Teneriffe, have very similar characters.

The rock from Lake Suess consists partly of spherulitic and partly of red palagonite-looking material. It contains large sanidine-phenocrysts remarkable for their clearness and freedom from inclusions. A few small

[1] This Magazine, 1900, vol. xii, p. 263, fig. 3, pl. 3.
[2] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 212.

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crystals of a hornblende near to catophorite are also present: these show pleochroism:—

a = pale yellow with a tinge of red,
b = smoky rose-red,
c = greenish-yellow,

as determined in prismatic sections and in one showing a well-marked hornblende cleavage inclined at an angle of about 124°.

The rock from Lake Nakuru is a glassy black scoria consisting of a streaky intermixture of a nearly colourless glass with a deep brown almost opaque glass. Small phenocrysts of olivine, aegirine, and anorthoclase occur very sparingly. The colourless glass is crowded with skeleton-crystals of very pale green augite, and brown needles, together with minute oval patches differentiated from the clear glass by being less transparent and of a brownish tinge: in many cases these patches are seen to be halos round needle-shaped microliths and skeleton-crystals of felspar.

A chemical analysis of this rock gave the following result:—

SiO_2	...	...	64·00
TiO_2	...	...	0·78
Al_2O_3	...	...	10·43
Fe_2O_3	...	...	6·30
FeO	...	...	3·86
MnO	...	...	0·37
CaO	...	...	1·45
MgO	...	...	0·34
Na_2O	...	...	7·59
K_2O	...	...	4·59
H_2O	...	...	0·17
			99·88

Of clear, compact, colourless (in thin section) obsidians there are specimens from Equator Peak (277) and from Lake Naivasha. These consist almost wholly of glass containing very minute felspar-microliths (visible between crossed nicols) and a few minute needles of aegirine.

An analysis of the rock from Lake Naivasha gave the following result (I), which shows the close relation of the rock to the pantellerites; the analysis[1] of a specimen of which from Cuddia Mida, Pantelleria, is given under II:—

[1] Rosenbusch, Elemente d. Gesteinslehre, 1898, p. 257.

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	I. Lake Naivasha.	II. Pantelleria.
SiO_2	70·61	69·02
TiO_2	0·15	—
Al_2O_3	8·59	10·09
Fe_2O_3	2·52	4·42
FeO	5·96	4·56
MnO	0·34	—
CaO	0·61	1·45
MgO	0·07	0·76
Na_2O	6·77	6·29
K_2O	4·46	3·70
H_2O	0·10	—
	100·18	100·29

(iv) *Kenytes* (' *Trachydolerites* ').

From the Rift Valley come, besides the phonolites and trachytes, also rocks similar to those which occur so extensively on Mt. Kenya, both as lava-flows and as part of the core, and to which Professor Gregory has given the name kenyte.

As previously pointed out by me[1] and also recently by Dr. L. Finckh[2], precisely similar rocks occur on Kilimandjaro. They have been referred by Dr. Finckh to Rosenbusch's somewhat unsatisfactorily named group of ' trachydolerites.' The rocks agree so far with Rosenbusch's definition of this group in having characters in some respects intermediate between phonolites and tephrites. They would form, however, a distinct type (kenyte-type) of the group, especially characterized by the presence of anorthoclase as the prevailing felspar. I am inclined to regard them as members at the basic end of a phonolitic rock-series of which the pantellerites and comendites are the acid equivalents. Chemically at least, although not altogether mineralogically, they stand in fact at the basic end of the phonolitic series just described (p. 235). Some kenytes from Kilimandjaro (e. g. the so-called ' nepheline-basanite ' of Hyland) and from the Canary Islands (p. 256) are so far like phonolites that they contain nepheline and leucite. The results of chemical analyses which I have made of two specimens of kenyte from Mt. Kenya are given in the

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 221.

[2] Ueber die Gesteine des Kenya und des Kilimandjaro. Centralblatt Min., 1902, pp. 204–5.

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following table, in which are shown the chemical relationships of four members (basic, intermediate, and acid) of the phonolitic rock-series, viz.

I. Kenyte from the core of Mt. Kenya (Teleki Valley).
II. Kenyte from the lava-flow at the foot of Mt. Höhnel, Mt. Kenya.
III. Phonolite from the base of Mt. Höhnel, Mt. Kenya.
IV. Phonolitic obsidian from Lake Nakuru.
V. Obsidian (glassy soda-rhyolite) from Lake Naivasha.

	I. Kenyte.	II. Kenyte.	III. Phonolite.	IV. Phonolitic obsidian.	V. Soda-rhyolite.
SiO_2 . . .	53·98	53·80	58·37	64·00	70·61
TiO_2 . . .	0·57	0·31	0·21	0·78	0·15
Al_2O_3 . . .	19·43	18·46	16·65	10·43	8·59
Fe_2O_3 . . .	4·39	6·22	4·09	6·30	2·52
FeO . . .	2·05	0·40	3·03	3·86	5·96
MnO . . .	0·26	0·33	0·43	0·37	0·34
CaO . . .	2·04	2·53	1·66	1·45	0·61
MgO . . .	1·07	1·05	0·37	0·34	0·07
Na_2O . . .	8·81	7·09	7·28	7·59	6·77
K_2O . . .	5·27	5·46	5·46	4·59	4·46
P_2O_5 . . .	0·30	0·53	0·08	—	—
H_2O below 110°	0·13	0·85	0·96	—	—
H_2O above 110°	1·66	3·54	1·40	0·17	0·10
	99·96	100·57	99·99	99·88	100·18

Of the specimens of kenyte from the Rift Valley, rock (408) from Domo Larabwal appears to be a typical example precisely similar to the rock from the core of Mt. Kenya. The large porphyritic anorthoclases with inclusions of the base, and the very pale-green augite and altered olivine, are identical in character. These phenocrysts occur in a dense brown, apparently glassy base, in which a few felspar-microliths can be distinguished.

Other specimens are of a less glassy type, and show an approach to the phonolitic trachytes. These show phenocrysts of anorthoclase (generally not so plentiful nor so large as in the typical kenytes), a few small pale-green augites, and, still more sparingly, olivine in a more or less glassy base of felspar-laths with interstitial opacite (possibly altered soda-amphiboles) and a little augite. Specimens from the descent to Lake Elmenteita (248), crags behind Naivasha Camp (250), east of Mivironi

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(265), first swamp, Kikuyu (170), second swamp, Kikuyu (175) have a fine-grained base of felspar-microliths with intermixed streaky patches of more glassy material; but specimens from the ridge just west of Kedong Col, and from the ridge on the floor of the first fault valley in West Kikuyu, are of coarser grain and contain no glass.

II. Basalts.

To judge from the present collections, basalts play in the Rift Valley eruptions a very minor rôle compared with that of the phonolitic lavas.

In Professor Gregory's collection there are specimens from Kamasia and Laikipia, the Tana Steppes, south of Guaso Nyiro, and Kibwezi. In Sir Harry Johnston's collections, besides the basalt-scoria from Ankole, the only specimens of Tertiary felspar-basalts are from Kamasia. Specimens, however, of what are probably much more ancient basalts occur in association with the gneiss at Bedden in the Nile Province and at Ketosh in the Elgon District: an intrusive basalt also occurs in the ferruginous shales of Unyoro.

Of the Laikipia basalts, those of Domo Larabwal are remarkable for the number and large size of the phenocrysts of olivine and purple augite. They are mainly magma-basalts near to limburgite, and consist of a very dense glassy base, containing much magnetite, some purple augite, and only a little felspar, in which are distributed numerous and large phenocrysts of clear olivines and pale-brown to purple zonal augites. The basalts from south of Rangatan Nado (443, 447) are of a different and more ordinary type and consist of a fine-grained mesh of felspar-laths, magnetite, and much purple augite, with only a few small phenocrysts of olivine and augite.

A specimen from Malungu, Tana Steppes (555), is similar to the basalts of Domo Larabwal in containing large phenocrysts of olivine and augite (sometimes intergrown), but is much more felspathic, as it contains phenocrysts of long prismatic plagioclase-felspars, and also felspar-laths in the base together with the augite and magnetite: the latter is in rods, often arranged at right-angles to the principal axis of the olivine.

The ropy basalt-lava of Kibwezi (851) consists of a dense, nearly opaque, glassy base, in which are distributed olivine-phenocrysts in large amount with some shar ly-defined felspar-laths and only a little augite: on the surface, the rock consists of a clear yellow glass containing the same phenocrysts.

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Of the specimens from Kamasia some are ordinary felspar-basalts consisting of phenocrysts of plagioclase, yellow augite, and much altered olivine in a base of felspar-laths, augite, and magnetite, but others show characters in some respects intermediate between the phonolitic rocks and basalts, and may thus be referred perhaps to Rosenbusch's 'trachy-dolerites.'

A specimen of this kind from the slope of the basalt-plateau of Kamasia (389) consists of a trachytic mesh of felspar-laths, mostly in Carlsbad-twins with low angles of extinction, interspersed between which are distributed irregular grains of purple augite and some magnetite. With the purple augite is also a little green aegirine and catophorite, and some of the purple augites have green edges.

III. Nephelinites, etc., from Mt. Elgon, the Nandi District, and the Foot of Ruwenzori.

These basic rocks, and also probably the phonolites containing sphene described on p. 239, belong to a later period of eruption than the cossyrite- and catophorite-bearing phonolitic rocks of the Rift Valley. They represent therefore, in all probability, the later differentiation products of the soda-rich magma which gave birth to these earlier phonolitic lavas. Besides differing from the latter in greater basicity and larger contents of lime and magnesia, they appear to be further differentiated from them by the greater amount of titanic acid, which in the more basic rocks is present in the mineral *perofskite*, and in the more acid in *sphene*.

The nephelinites consist mainly of yellow augite, nepheline, and some magnetite, but in some cases the nepheline is partially, and in others almost wholly, replaced by melilite. In the latter case the rocks, to be consistent in rock-nomenclature, may be referred to as *melilitites*, although the name is somewhat cacophonous.

At a height of 8000 feet on Mt. Elgon occurs a *tuff* containing fragments not only of altered nephelinite, but also of the borolanite-like rock and of the jacupirangite-like rock described below.

Nephelinites and melilite-nephelinites.

These are dark basaltic-looking rocks generally showing numerous fairly large phenocrysts of augite.

A specimen from Mt. Elgon (8000 feet) shows under the microscope numerous phenocrysts of yellow augite and a few rectangular sections

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of an altered mineral (probably melilite) in a dense base consisting of nepheline in square and hexagonal sections with interstitial augite-needles and grains of magnetite. Large grains of magnetite are scattered through the slide, some included in the augite-phenocrysts. These augites are very irregular in outline, are not pleochroic, show well-marked nearly rectangular cleavage, and give extinctions as high as 42°.

Two specimens from a lower elevation on Mt. Elgon (7000 feet) present very similar characters, but approach to augitites, since the nepheline in the base is much less prominent, and in one appears to be wholly replaced by glass: in the latter rock, besides the augite-phenocrysts, there are also a few altered olivines, and some of the augite-needles of the base where they project into cavities filled with analcite (?) have terminations of grass-green aegirine. In neither of these rocks are there any phenocrysts of altered melilite or nepheline.

From the Sigowet Hills and Seget Valley, Nandi, come nephelinites of a less basic character, in which the phenocrysts consist mainly of fairly large nephelines and very little augite: rectangular phenocrysts of altered melilite (?) are also present. The base is similar to that of the nephelinite of Mt. Elgon (8000 feet), and contains much magnetite, but the nepheline, in fairly large rectangular and hexagonal sections, is in greater amount. Scattered through the slide are fairly large grains of purple perofskite.

Similar in many respects to the nephelinites of Mt. Elgon are two rocks from the Nandi District, one from the bed of the upper waters of the Lower Kedowa River, and the other from the Nyando River. They contain precisely similar phenocrysts of yellow augite; but nepheline, both as phenocrysts and in the base, is in the first partially, and in the second almost wholly, replaced by melilite. The augite-phenocrysts are large, but not so numerous as in the Mt. Elgon rocks: in the Nyando rock most of them are surrounded by a fringe of melilite-needles.

The *melilite*-phenocrysts are fairly large and have a slight brown tinge; some show rectangular sections with straight extinction, but most are rounded and partially reabsorbed: the refraction is fairly high, but the double refraction low, and they depolarize in bluish-grey tints. Prismatic sections of the phenocrysts and the needles of the groundmass compensate with the quartz-wedge across the length like the Hochbohl melilite, and one of the phenocrysts, which remained dark between crossed nicols, showed a good negative uniaxial figure. The dense groundmass of these rocks consists of melilite-needles, some rectangular sections of nepheline, much yellow augite in needles, much magnetite,

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and some glass. Perofskite, the common associate of melilite, is present, but not in large amount, in grains sometimes enclosed in augite and also in the larger grains of magnetite.

In order to isolate the melilite in the Nyando rock for further examination, a mineral separation by means of methylene iodide was made on powdered material which had been passed through a sieve of 100 meshes to the inch. By continued dilution of the methylene iodide with benzol the material was separated into the following portions :—

(1) Sank in methylene iodide.
Under the microscope this portion was seen to consist mainly of magnetite (separable by a magnet) and yellow augite : perofskite was also seen.

(2) Sank with spodumene.
Mainly augite with some magnetite.

(3) Sank with tourmaline.
Augite and magnetite with attached fragments of the base, and grains of melilite in large amount. Many of these melilite grains showed a well-defined central negative uniaxial figure; they gelatinized with hydrochloric acid, and showed the presence of silica, alumina, and lime.

(4) Sank with calcite.
Mainly aggregates of magnetite, augite, and base, with a little melilite, some grains showing good uniaxial figures.

(5) The residue consisted mainly of aggregates of augite, magnetite, and base, with a few colourless grains, probably of nepheline, and alteration products.

In connexion with these rocks from Mt. Elgon, it is of interest to note the occurrence in the volcanic region at the foot of Ruwenzori of a perofskite-bearing nephelinite, suggesting the idea that the eruptions in this region on the western side of Lake Victoria Nyanza belong to the same period as those of Mt. Elgon. A specimen of this rock from between Katwe and Chukaronga in the Scott Elliot collection is a fine-grained basaltic-looking rock showing no phenocrysts. Under the microscope it is seen to consist of a fine-grained aggregate of small prismatic pale greenish-yellow augites, magnetite-grains, and numerous small crystals of purple perofskite uniformly distributed in a paste of nepheline and a little isotropic material. The perofskite has precisely the same colour as the mineral from Mt. Elgon : many of the crystals

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are apparently interpenetration twins formed of four lozenge-shaped individuals fitted together in the form of a cross with the axes at right-angles. Other sections of twin-crystals show only three individuals with axes inclined at 120°. These appearances are much in favour of the view that the cubic character of perofskite is due to mimetic twinning, and that the optical anomalies are therefore not due to secondary causes as advocated by Klein and Ben Saude.

A mineral separation of this rock in order to isolate the nepheline was made in the same way as in the case of the preceding melilite-rock. The following particulars are given to indicate the degree of separation which can be effected by means of heavy liquids in the case of a very fine-grained rock. By continued dilution of the methylene iodide a portion of the rock which was ground down so as to pass through a sieve of 120 meshes to the inch was divided into the following parts:—

(1) Sank in methylene iodide, tourmaline floating.
Magnetite, augite, and perofskite: grains of the latter decomposed by sulphuric acid gave a strong titanic acid coloration with hydrogen peroxide.

(2) Sank with tourmaline, calcite floating.
Mainly augite; a little magnetite.

(3) Further diluted, calcite still floating.
Mainly augite, fine-grained.

(4) Further diluted, but calcite still floating.
Aggregates of augite and nepheline with a little attached magnetite and perofskite: coarse-grained.

(5) Sank with calcite, quartz floating.
Similar aggregates to (4), but a larger proportion of nepheline and little or no magnetite.

(6) Sank with quartz, moonstone floating.
Grains consisting mainly of nepheline and probably a little felspar, but still with a little augite attached.

(7) Sank with moonstone, leucite floating.
Mainly nepheline with a few grains giving oblique extinction (felspar): some grains still with augite attached. A portion of the nepheline was tested chemically: it gelatinized with hydrochloric acid, and showed the presence of silica, much alumina, and soda, with only a little lime.

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(8) Sank with leucite.

Brown alteration products and a little nepheline.

(9) A slight residue left floating consisted of similar alteration products.

Phonolite with Melanite, allied to Borolanite.

This rock occurs in fragments in a tuff from Mt. Elgon (8000 feet). Under the microscope (fig. 5, pl. V) are seen phenocrysts of nepheline, sharply defined small aegirine-augites, and large zonal melanites in an altered groundmass probably originally consisting of nepheline and felspar with some cossyrite. The nepheline-phenocrysts are large and plentiful, and give sharply defined rectangular and hexagonal sections: one section shows inclusions of perofskite. The aegirine-augites are pleochroic, from pale yellow to green, and have a border or terminations of grass-green aegirine. The melanites contain inclusions of aegirine-augite and sphene.

Augite-Perofskite-Magnetite rock allied to Jacupirangite.

In the same tuff from Mt. Elgon (8000 feet) were dark patches consisting of a coarse-grained aggregate (fig. 6, pl. V) of yellowish brown augites (precisely similar to the augite of the nephelinites), purple perofskites, and magnetite, with some interstitial apatite and a little biotite. The perofskite is doubly refractive, and shows between crossed nicols striae parallel to the cube-faces. This rock suggests analogies with the jacupirangite of Brazil, and with some of the basic differentiation products of the nepheline-syenite of the island of Alnö, Sweden.

Tuff from the foot of Ruwenzori.

The specimen of this tuff in the Scott Elliot collection (No. 96) has been already referred to by me in a paper by Mr. M. Fergusson on the geology of Tanganyika northwards[1]. It is from one of the small volcanic cones which with small crater-lakes are found so extensively on the plain round Ruwenzori. It is of interest from the character of the lapilli which, with fragments of biotite, felspar, and magnetite, constitute the bulk of the rock. These lapilli vary considerably in size, but almost all of the larger ones consist mainly of fragments of gneissic rocks and amphibolites or of mineral fragments (chiefly biotite) from them, enclosed in only a thin film of volcanic material. These fragments have obviously been torn from the walls of the vent during the eruption, and after having been coated with the molten lava have then been ejected as lapilli. In

[1] Geol. Mag., 1901, vol. viii, p. 368.

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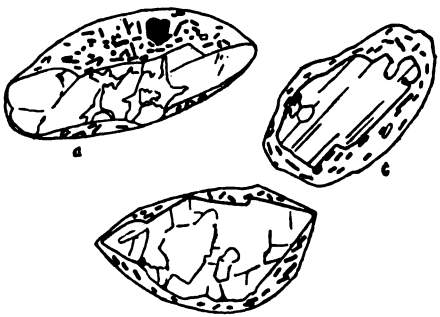
the adjoining figure three of these lapilli (*a*, *b*, *c*) are represented as seen under the microscope under a magnification of about 16 diameters. In *a* and *b*, fragments consisting of aggregates of felspar and quartz, and in *c*, a piece of biotite, are seen surrounded by a film of glassy volcanic



Lapilli in tuff at the foot of Ruwenzori. They consist of fragments of ancient rocks torn from the walls of the vent and enclosed in a film of lava.

rock containing felspar-needles[1], magnetite, and a little yellow augite. In many of the lapilli the felspar of the enclosed fragment is seen to consist mainly of microcline. One fragment enclosed in lava is an amphibolite, consisting mainly of a pleochroic (yellow to green) hornblende, and pale green diopside with some quartz and felspar.

Comparison of Phonolitic Rocks of British East Africa with those of Pantelleria, the Canary Islands, St. Helena, Ascension, Aden, and Abyssinia.

In the preceding pages attention has been called several times to similarities between phonolitic rocks of the Great Rift Valley and those of Pantelleria and the Canary Islands. In the present section this similarity will be further emphasized by a brief description of particular specimens from these localities, and at the same time somewhat similar rocks from St. Helena, Ascension, and Aden will be discussed.

Pantelleria.

Rosenbusch[2] has described the occurrence in phonolitic trachytes from Pantelleria of the same pleochroic (brown to violet) mineral (catophorite) as was found by Mügge in the 'acmite-trachyte' from the Azores.

A specimen of phonolitic trachyte from Montagna Grande in the British Museum collection shows large phenocrysts of anorthoclase, a

[1] Many of the needles consist of calcite, and possibly represent altered melilite.

[2] Mikr. Phys. Ges., 3rd ed., 1896, vol. ii, p. 812.

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few green aegirine-augites, and some olivine (with inclusions of magnetite) in a fine-grained trachytic mesh of felspar-laths with interstitial catophorite, augite, and a little cossyrite. This rock is very similar to the rocks from the Rift Valley, having characters intermediate between kenytes and phonolitic trachytes, described on p. 247.

To the more acid type of phonolitic trachyte belongs a specimen from Punta Pozzolana, in which phenocrysts of anorthoclase occur in a base of felspar-laths and micropoecilitic patches of quartz with interstitial thickly distributed cossyrite, catophorite, and augite. The rock is thus almost precisely similar to the phonolitic quartz-trachytes described on p. 242.

A phonolitic obsidian from Montagna Grande, consisting of a brown glass with small, nearly opaque, spherulitic patches and a few small phenocrysts of rounded deep reddish-brown cossyrite, grass-green aegirine and anorthoclases, resembles (except for the presence of the cossyrite) the spherulitic rocks described on p. 244.

As already pointed out, the glassy pantellerites are in chemical composition very similar to the glassy soda-rhyolites of the Rift Valley.

In Pantelleria, therefore, there appears to be a series of alkali-rich rocks analogous to the series found in the Rift Valley. The range, however, appears to be more limited, with silica percentages varying from about 60 to 74, according to the analyses of Förstner[1], and no rock strictly analogous to the typical glassy kenyte from Mt. Kenya has been found in the British Museum collection from Pantelleria. Its place, however, may possibly be taken by a rock from Punta Pozzolana, which has characters intermediate between those of a basalt and trachyte, and may thus be referred to Rosenbusch's 'trachydolerites.' In this rock very large phenocrysts of anorthoclase, with some small purple augites and a little olivine, occur in a medium-grained ground-mass of felspar-laths (mainly plagioclase), purple augite, and magnetite in skeletal crystals.

Canary Islands.

The occurrence of catophorite and cossyrite accompanying aegirine in phonolitic rocks from Gran Canaria and Teneriffe has already been pointed out in a previous paper[2]. Some of the phonolites are precisely similar to the phonolite from Mt. Kenya with nepheline surrounded by aegirine, and the phonolitic trachytes are similar to those described on p. 241. In some of these, however, the ordinary catophorite is replaced by ragged patches of a soda-amphibole presenting somewhat different pleochroism,

[1] Förstner, Nota preliminare sulla geologia dell' Isola Pantelleria. Boll. Com. Geol. d'Italia, 1881, vol. xii, pp. 523–56.

[2] This Magazine, 1901, vol. xiii, p. 89.

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from pale grey with a tinge of green for vibrations along the line of extinction ($a : c = 80°$) in prismatic sections, to pale smoky brown with a tinge of purple at right-angles.

The coarse-grained *theralite*, fragments of which have been ejected as bombs in Gran Canaria, presents some points of resemblance with the crystalline rock from the core of Mt. Kenya[1]. It consists of a coarse-grained aggregate of long prismatic plagioclastic felspars and plates of nepheline, with large pleochroic (pale yellow to pinkish-purple) augites surrounded by a zonal intergrowth of pleochroic (light brown to deep reddish-brown) basaltic hornblende similar to that in the rock from Mt. Kenya: the same hornblende is further plentifully distributed in small prismatic crystals together with sphene and apatite in patches grouped round the augites.

In this connexion may be mentioned a coarse crystalline rock (probably a bomb) from Pena, Fuerteventura, having the characters of an *essexite*. It consists of a coarse-grained aggregate of labradorites (symmetrical extinction of 32°) with large ophitic plates of the same basaltic hornblende as in the preceding rock, together with some biotite, pale purple augite (often enclosed in the hornblende), sphene, and apatite.

Glassy phonolitic rocks from Teneriffe (Vallée de Ucanca), with brown spherulites, and porphyritic anorthoclases and small pale-green augites, are very similar to some of the glassy rocks from the Rift Valley described on p. 244.

The striking resemblance of the rocks from the Canary Islands with those of the Rift Valley is further emphasized by the occurrence from the Caldera of Gran Canaria of a typical *leucite-kenyte*, very similar, both macroscopically and microscopically, to the kenyte of Mt. Kenya. The rock is of a deep-brown colour, and shows numerous fairly large phenocrysts of anorthoclase. Under the microscope, phenocrysts of a pale purple augite and large anorthoclases showing minute twin-striations are seen in a glassy base (dense with brown dusty inclusions), through which are scattered a few felspar-laths and fairly numerous bright hexagonal and octagonal sections of leucite showing characteristic zonal bands of dark inclusions.

St. Helena.

In this island, with the basalts are associated phonolitic rocks bearing some relation to the rocks of the Rift Valley. Thus a specimen in the British Museum collection[2] from the rock-mass known as Lot's Wife is

[1] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 208.

[2] The specimens here described belong to a collection presented by Mr. R. L. Antrobus in 1891.

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a phonolite somewhat like the rock from Mt. Kenya, showing minute nephelines surrounded by aegirine, which also occurs in feathery patches together with the same pale greyish-brown amphibole as in the phonolitic trachyte of Gran Canaria described above.

Other specimens of phonolitic rocks from the prominent peak Lot are of a somewhat different type, and present many points of similarity, both macroscopic and microscopic, with the rocks from near Axum, Abyssinia, described (and figured) as allied to sölvsbergite in a previous paper[1]. Like the Abyssinian rocks they show a peculiar surface shimmer, due to the platy arrangement of the felspars, and the most prominent constituents are grass-green aegirine in shreds and small grains interspersed between lath-shaped felspars (probably anorthoclase) giving curious undulose extinctions and showing very conspicuous wavy lines of parting (see fig. 4, pl. 8, l. c.); but in the St. Helena rocks, in addition to these constituents, there are present small nephelines and a little cossyrite. The rocks are medium-grained, the felspar-laths being fairly large; in some cases there is an approach to porphyritic structure by larger felspars occurring in a base of smaller laths.

The occurrence in St. Helena of these isolated peaks of phonolite projecting through the overlying basaltic lavas reminds one of the similar association of phonolites and basalts on Fernando Noronha and the Little Island of Trinidad, South Atlantic[2].

Ascension.

In this island the augite-trachytes and obsidians described by Renard[3] appear to play the same rôle in association with the basaltic lavas as the phonolites with the basalts in St. Helena.

Examination of specimens in the British Museum collection shows that most of these trachytes are of a distinctly soda-rich phonolitic type, and that they contain anorthoclase-felspar and the soda-amphiboles, riebeckite and cossyrite. As pointed out by Renard, quartz is present in these trachytic rocks, but there would appear to be no good reason for regarding it in all cases as of secondary origin. In most of the specimens it occurs, in fact, in the base, depolarizing in patches and enclosing felspar-laths, and thus forming a micropoecilitic structure of precisely the same character as that in the phonolitic quartz-trachytes and in the riebeckite-rhyolites of the Rift Valley described on p. 242.

The *riebeckite* occurs in these rocks in characteristic moss-like patches

[1] This Magazine, 1900, vol. xii, p. 265, and fig. 4, pl. 8.

[2] This Magazine, 1900, vol. xii, pp. 317–23.

[3] Challenger Reports, Physics and Chemistry, vol. ii, pt. 4, pp. 39–74.

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scattered through the base: it shows the usual pleochroism from yellowish-brown with a tinge of green for vibrations across the length of prismatic sections to deep indigo-blue and opaque along the length, to which the a-axis of the indicatrix is nearly parallel. Accompanying the riebeckite, and in some cases wholly replacing it, is cossyrite: aegirine and also aegirine-augite are generally present, but in comparatively small amount. In a specimen from Green Mt., besides aegirine, which is scattered in small grains uniformly over the slide, and cossyrite, there occurs the hornblende with pleochroism from reddish-brown to deep bluish-brown or opaque described by Renard[1] as also occurring in crystals formed by sublimation in the crevices of the rock. In some of the other specimens this hornblende occurs with a zonal intergrowth of riebeckite. The phenocrysts in these rocks consist of sanidine, and of anorthoclase showing the characteristic minute twin-striations.

Some of these trachytes are strikingly similar to the riebeckite-trachytes from Senafé, Abyssinia, described in a previous paper[2]. That some of them should be referred to the soda-rhyolites is suggested by the results of the chemical analysis of Klement quoted by Renard[3].

In the following table this analysis of trachyte from Ascension is reproduced under I, while for comparison are given under II that of the comendite from Comende, Sardinia; under III that of Klement's analysis of obsidian from Ascension; under IV that of a quartz-keratophyre from the Mühlenthal; under V that of a pantellerite from Mt. S. Elmo, Pantelleria; and under VI that of the glassy soda-rhyolite from the Rift Valley described on p. 245.

	I.	II.	III.	IV.	V.	VI.
SiO_2 ...	70·99	74·76	72·71	70·97	69·02	70·61
TiO_2 ...	—	—	—	—	—	0·15
Al_2O_3 ...	14·84	11·60	12·80	13·84	10·09	8·59
Fe_2O_3 ...	3·76	3·50	2·64	3·21	4·42	2·52
FeO ...	0·35	0·19	1·48	0·78	4·56	5·96
MnO ...	trace	—	trace	0·12	—	0·34
CaO ...	0·60	0·07	0·58	1·26	1·45	0·61
MgO ...	0·14	0·18	0·10	0·20	0·76	0·07
Na_2O ...	5·94	4·85	6·50	6·27	6·29	6·77
K_2O ...	2·40	4·92	3·87	1·57	3·70	4·46
H_2O ...	0·40	0·64	0·48	0·74	—	0·10
	99·42	100·21	101·16	98·96	100·29	100·18

[1] Loc. cit., p. 53. [2] This Magazine, 1900, vol. xii, p. 94. [3] Loc. cit., p. 47.

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The obsidians of Ascension, which are seen by the above analysis to be the glassy equivalents of the 'augite-trachytes,' have the chemical composition of soda-rhyolites. One specimen in the British Museum collection shows under the microscope small phenocrysts of anorthoclase in a glassy base crowded with felspar-microliths: one or two small grains of aegirine and aegirine-augite and one of olivine are also present.

The close connexion between these obsidians and comendites and quartz-keratophyres is seen from the above analyses. They differ from pantellerites and the obsidian from the Rift Valley for the most part only in their lower percentage of oxides of iron.

Aden.

Many of the trachytic and phonolitic rocks of Aden show some points of resemblance with the rocks of the Rift Valley. Thus a pale green glassy rock in the British Museum collection showing marked flow-structure has a remarkable similarity with some of the 'kenytes' from Mt. Kenya. Under the microscope it shows small phenocrysts of anorthoclase, with the twin-striations well marked, in a dense glassy base crowded with minute felspar-microliths, and interstitial irregular grains of aegirine-augite and opacite (suggestive of altered cossyrite): amongst the phenocrysts are one or two small crystals of aegirine-augite and, very sparingly, olivine.

Another specimen is a phonolitic quartz-trachyte similar to those from the Rift Valley (p. 242). In this rock small phenocrysts of sanidine and anorthoclase with, very sparingly, aegerine-augite and fairly large olivines occur in a trachytic mesh of felspar-laths with needles of grass-green aegirine, micropoecilitic quartz, and patches of ferrite and opacite very suggestive of altered cossyrite.

Abyssinia.

The general resemblance of phonolitic rocks from the neighbourhood of Axum and of Senafé, Abyssinia, to rocks from the Rift Valley and from St. Helena and Ascension has been sufficiently demonstrated in the preceding pages. In addition, two glassy rocks may be mentioned here as very similar to some of the spherulitic phonolitic obsidians of the Rift Valley. The specimens belong to the Blanford collection[1] and come, one from the Ferra Pass, near Belago, and the other from the

[1] The collection was made by Dr. W. T. Blanford when acting as geologist to the Abyssinian Expedition of 1868 under Sir Robert Napier.

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Alagi Pass. They are deep-brown spherulitic glassy rocks showing flow-structure and phenocrysts of anorthoclase with a few pale green augites and, very sparingly, olivine.

General Conclusions and Summary.

Gneisses and schists with granulites form the basement rocks of British East Africa. Above them on the western side of the Great Rift Valley in the Victoria Nyanza region occur the ferruginous schists, shales, and sandstones of the Karagwe series, part of which may probably be referred to the Cape system of South Africa and the Cuddapah series of India. Through these ancient rocks in Tertiary times were erupted the lavas from Mts. Kenya, Kilimandjaro, and Elgon, and from the craters of the Rift Valley and those at the foot of Ruwenzori.

With the exception of basalts from Laikipia and Kamasia and of basic nephelinites and melilite-rocks from the Mt. Elgon district and Ruwenzori, the lavas are mainly of a phonolitic type: all have doubtless been derived from a soda-rich nepheline-syenite- or theralite-magma. They present a remarkable example of a *rock-series* varying in basicity from acid riebeckite-rhyolites to basic phonolites and kenytes, but with all the members characterized, chemically, by the low contents of lime and magnesia and high percentages of alkalies (especially soda) and oxides of iron, and mineralogically, by the presence of anorthoclase and for the most part of both soda-pyroxenes and soda-amphiboles.

In their characters these phonolitic lavas present striking analogies with eruptive rocks from other parts of Africa and the neighbouring islands. This is especially true of the rocks of Pantelleria, the Canary Islands, and Abyssinia; but the phonolitic rocks of St. Helena, Ascension, and Aden also have many features in common with those of British East Africa and Abyssinia. The eruptive rocks of Madagascar are mainly of a phonolitic type [1], and nepheline-syenites occur there, and also in the Transvaal and on the west coast of Africa on the Los Islands, Sierra Leone. Nephelinites and leucitites are also the principal lavas of the Etinde volcano in the Cameroons [2]. Altogether there would seem to be a wonderful uniformity about the eruptive rocks of Africa and the adjacent islands, indicating that they have all been derived from alkali-rich nepheline-syenite- or theralite-magmas.

[1] See Lacroix, Les roches alcalines caractérisant la province pétrographique d'Ampasindava. Nouv. Archives du Muséum d'Histoire Naturelle. Paris, 1902, sér. 4, tom. iv, fasc. 1, 152 pp., 10 pls.; and this Magazine, 1900, vol. xii, p. 272.

[2] E. Esch, Sitz.-Ber. Akad. Wiss. Berlin, 1901, pp. 277, 400.

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This may be, however, only a part of a wider generalization, for the association of basalts with alkali-rich phonolitic rocks appears to be common not only to the west African islands, but to the great Atlantic volcanic chain generally. This association, for example, is met with not only in the islands of Ascension and St. Helena, but also in the islands of Fernando Noronha, the Little Island of Trinidad, and the Tristan d'Acunha group. Basalts are the prevailing rocks in the Faroe Islands and in Iceland, and in the latter locality they are associated with obsidians rich in alkalies and poor in lime and magnesia. In the Hebrides also the Tertiary basalts are associated with 'pitchstones,' many of which contain augite and anorthoclase and are thus related to pantellerites. The two European offshoots from the great Atlantic chain are also characterized to a large extent[1] by alkali-rich lavas associated with basalts. This is the case in the volcanic regions of Auvergne, the Eifel, and the Bohemian Mittelgebirge belonging to the northern branch; while in the southern Mediterranean branch the present basaltic eruptions are mainly of a type rich in alkalies, and the trachytic lavas have some points of resemblance (e. g. the Arso trachyte) with the 'acmite-trachyte' of Terceira and the rocks of the kenyte series[2]. To this Mediterranean branch belong also the soda-rich lavas of Pantelleria and the phonolites of Tripoli. The lavas of Santorin, however, appear to be connected with the andesitic eruptions of Asia Minor.

Thus of the four great volcanic chains running north to south, the great Atlantic chain with its European branches, and the minor chain along the east coast of Africa including Madagascar, are characterized by the association of basalts and alkali-rich phonolitic rocks, whereas in the two other great Pacific chains (one from Alaska through Japan and the East Indies to New Zealand, and the other down the western coast of the American continent) andesites are the prevailing lavas.

In this connexion it is of interest to recall the fact which has been noted that the eruptive rocks in the United States become more and more rich in soda as one proceeds from west to east, i. e. from the Pacific towards the Atlantic volcanic chain[3]. Similarly in Europe and Asia the lavas become less rich in alkalies and more andesitic in character (e. g. the Hungarian andesites and the andesitic lavas of Santorin and

[1] With the exception of the Hungarian andesites.

[2] The 'bread-crust' bombs of Lipari (the 'volcanite' of Hobbs, Zeits. Deutsch. geol. Gesellschaft, 1893, vol. xlv, p. 578) are, by their mineral contents at least, more closely connected with the kenyte-series (pantellerites) than with the dacites.

[3] The lavas of the West Indies, however, as we have recently seen, still rather conform to the Pacific than to the Atlantic type.

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Asia Minor) as one proceeds from west to east, i. e. from the Atlantic towards the Pacific volcanic chain.

To the basalt-phonolite type appear to belong the eruptive rocks of Kerguelen and of South Victoria Land in the Antarctic Ocean, where basalts are associated in the former locality with phonolites, and in the latter with phonolitic trachytes belonging to the kenyte series [1].

In New Zealand the two types appear to effect a junction, for whereas in the South Island at Dunedin occur basalts with phonolitic rocks similar to those of Cape Adare, in the North Island andesites are the prevailing lavas.

List of Localities.

In conclusion is appended a list of the principal districts in British East Africa from which the specimens described in the preceding pages were collected, with the names of the rocks [2].

Archaean Plateau (Lugard's Falls on the Sabaki River, Iveti Mts., &c.)	*Gneisses, granulites, and amphibolites.*
Athi and Kapte Plains	*Phonolites.*
Kikuyu . . .	*Phonolites, phonolitic trachytes, obsidians, and kenytes.*
Laikipia . . .	*Phonolites, phonolitic trachytes, kenytes, and basalts.*
Baringo District (Kamasia)	*Phonolites, phonolitic trachytes, and basalts.*
Mau District, including Lake Naivasha, Nakuru, &c.	*Phonolites, phonolitic trachytes, riebeckite-rhyolites, and pantellerites.*
Nandi District .	*Phonolites, melilite-nephelinites, granite, and gneiss.*
Mt. Elgon . . .	*Nephelinites, tuffs, and rocks related to borolanite and jacupirangite.*
Elgon District .	*Gneisses, granites, and diabase.*
Busoga	*Ferruginous schists, shales and sandstones, quartzite, granite, diabase, pegmatite, laterite and ironstone.*
Bukedi	*Gneiss and schist, granite, pegmatite, quartzite.*

[1] See Prior, Report on the Rock-specimens, p. 328, in Report on the Collections of Natural History made in the Antarctic Regions during the voyage of the 'Southern Cross.' London, 1902.

[2] A list, with localities, of the specimens in Sir Harry Johnston's collections from Uganda, is given in his book 'The Uganda Protectorate.' London, 1902.

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Uganda Province	*Ferruginous shales and sandstones, quartzite, phyllite, diatomaceous earth* (8 *miles west of Katonga River*).
Ankole	*Phyllites, ferruginous shales and sandstones, and basalt scoria.*
Toro (Ruwenzori)	*Gneiss, schists, epidiorite, nephelinite with perofskite, tuffs.*
Unyoro . . .	*Ferruginous schists, shales, and phyllites; sandstone, quartzite, gneiss, and granulite.*
Nile Province .	*Gneiss and basalt.*

EXPLANATION OF PLATE V.

Microscope-sections of rocks from British East Africa.

Fig. 1.—Garnet-hornblende-granulite from five days west of Hameye (p. 230).
Pink garnet and green hornblende in a groundmass of plagioclastic felspar.
Magnification 10 diam., 2 inch objective.

Fig. 2.—Phonolite from Doenyo lol Mwaru (p. 238).
Portion of the groundmass highly magnified, showing grass-green aegirine, smoky rose-red catophorite, and nearly opaque reddish-brown cossyrite.
Magnification 100 diam., ⅛ inch objective.

Fig. 3.—Phonolite from south of Lari lol Morjo (p. 238).
Small colourless sanidines, and tufts of green aegirine, deep red-brown cossyrite, and some catophorite in a groundmass of felspar-microliths and altered nepheline.
Magnification 20 diam., 1 inch objective.

Fig. 4.—Phonolite from Kamnye River (p. 238).
Phenocrysts of sanidine and nepheline, and patches of grass-green aegirine, deep brown cossyrite, and sky-blue amphibole near to riebeckite.
Magnification 10 diam., 2 inch objective.

Fig. 5.—Phonolite with melanite, allied to borolanite, from Mt. Elgon (p. 253).
Phenocrysts of nepheline, green aegirine-augites with terminations of aegirine, and deep-brown melanite.
Magnification 10 diam., 2 inch objective.

Fig. 6.—Rock allied to jacupirangite from Mt. Elgon (p. 253).
Yellow augite, purple perofskite, and magnetite.
Magnification 10 diam., 2 inch objective.

The plate has been executed at the Oxford University Press by the three-colour collotype process from a water-colour painted by Miss E. Drake. On the whole the original colours have been fairly well reproduced, although not with absolute truthfulness.

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Some new crystal-forms on Krennerite.

By G. F. Herbert Smith, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read June 10, 1902.]

SOME interest attaches to crystals of krennerite, since this mineral has apparently the same composition as calaverite, the crystalline development of which presents such peculiar features. After completing the study of crystals of the latter substance, the author naturally turned his attention to krennerite to ascertain whether any similar peculiarities were noticeable, but nothing abnormal could be detected.

Good crystals of krennerite are rare. The Mineral Collection of the British Museum has however a specimen from Nagyág, on which are dotted numerous small crystals possessing a large number of brilliant faces. This specimen was examined by Prof. H. A. Miers rather more than twelve years ago, and the measurements of one good crystal are recorded in this Magazine [1]. The author measured the same crystal and four other smaller crystals on the three-circle goniometer designed by him, and encountered a large number of minute faces representing forms hitherto unrecorded. The habit of the crystals is prismatic, the prism-zone being striated, and the colour is a bronze-yellow. The cross-section of the measured crystals varies from $0{\cdot}2 \times 0{\cdot}2$ to $0{\cdot}7 \times 0{\cdot}5$ mm.

The author has observed on these crystals all the forms previously recorded and in addition the following, which are new:— K (310), L (520), M (650), N (340), j (140), J (160), β (141), γ (582), f (231), a (562), r (142), x (342), y (221), R (542), δ (043), ϕ (343), ϵ (032), θ (054), χ (144), ψ (344), ξ (411), η (012), κ (013), λ (901), π (401), Π (502), and μ (104).

[1] 1890, vol. ix, pp. 184–6.

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Fig. 1 is reproduced from Prof. Miers's paper [1]. Fig. 2 illustrates the occurrence of some new faces on one of the smallest crystals measured.

In the table (p. 266) are given the calculated and the mean observed values of the distances and azimuths of the forms, when measured from a (100).

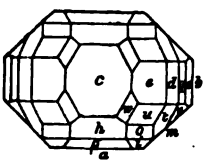

FIG. 1.

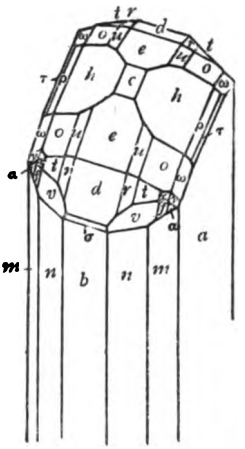

FIG. 2.

Krennerite.

The axial ratios are :—$a : b : c = 0{\cdot}9369 : 1 : 0{\cdot}5068$.

For comparison the ratios determined by previous observers are added :—

Vom Rath [2]	$a : b : c = 0{\cdot}9407 : 1 : 0{\cdot}5045$,
Schrauf [3]	$a : b : c = 0{\cdot}9396 : 1 : 0{\cdot}5073$,
Miers [4]	$a : b : c = 0{\cdot}9389 : 1 : 0{\cdot}5057$.

[1] The form (041), denoted by s in the figure, is called σ in the present paper, because the former letter has been assigned to (130) in accordance with the notation adopted in Dana's 'System of Mineralogy,' 6th edition.

[2] Zeits. Kryst. Min., 1877, vol. i, pp. 614–17.

[3] Zeits. Kryst. Min., 1878, vol. ii, pp. 235–9.

[4] Loc. cit.

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TABLE.

Measurements from *a* (100).

Form.		Calculated Values.		Observed Means.		Edges.	Limits of Observation.			Remarks. Characters of faces and images.
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.		Distance.	
		° ′	° ′	° ′	° ′		° ′	° ′	° ′ ° ′	
a	100	*	*	0 0	0 0	9	...	...	... ...	Large; images good.
K	310	,,	17 20½	,, ,,	18 8	2	...	...	17 55, 18 11	Minute.
L	520	,,	20 32½	,, ,,	20 31	2	...	...	20 30, 20 32	,,
k	210	,,	25 6	,, ,,	26 4	1	...	...	... ...	,,
l	320	,,	31 59	,, ,,	32 7	7	...	...	31 18–32 48	Small.
M	650	,,	37 59	,, ,,	38 22	1	...	...	... ...	Minute.
m	110	,,	*	,, ,,	43 8	12	...	...	42 49–43 28	Large; images good.
N	340	,,	51 19	,, ,,	51 25	1	...	...	... ...	Minute.
n	120	,,	61 55	,, ,,	61 55	12	...	...	61 24–62 39	Small; images fair.
s	130	,,	70 25	,, ,,	71 0	1	...	...	... ...	Striated.
j	140	,,	75 4	,, ,,	75 57	2	...	...	75 54, 76 0	,,
J	160	,,	79 55	,, ,,	80 20	1	...	...	... ...	,,
b	010	,,	90 0	,, ,,	90 0	9	...	...	... 90 6	Small; images fair.
γ	582	26 15½	59 6½	26 8	58 10	1	...	...	... ...	Minute.
β	141	,, ,,	76 32½	26 15	76 15	1	...	...	... ...	,,
σ	041	,, ,,	90 0	,, ,,	90 0	2	...	...	... 90 4	Small.
a	562	88 20	53 23	88 18	53 29	4	88 2–88 24		53 19–53 38	Minute.
f	231	,, ,,	59 16	,, ,,	59 29	1	,,	,,	... ...	,,
v	362	,, ,,	65 58	,, ,,	66 1	5	,,	,,	65 48–66 20	Small.
q	031	,, ,,	90 0	,, ,,	90 0	4	,,	,,	... 90 2	,,

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R	542	44 37	46 28½	44 85½	46 85	1	44 20—44 47	... ...	Minute.
y	221	,, ,,	52 46	,, ,,	52 43	2	,, ,,	52 29, 52 57	Small.
x	342	,, ,,	60 19	,, ,,	60 28	4	,, ,,	60 14—60 31	,,
t	121	,, ,,	69 12	,, ,,	69 11½	5	,, ,,	69 0—69 18	,,
r	142	,, ,,	79 15	,, ,,	79 18	4	,, ,,	79 0—79 23	,,
d	021	,, ,,	90 0	,, ,,	90 0	5	,, ,,	... 90 4	,,
e	032	52 45½	90 0	52 26	90 8	1	... ...	... ...	Minute.
ϕ	343	55 57	65 51½	55 0	67 0	1	... ...	... ...	,,
δ	043	,, ,,	90 0	,, ,,	90 0	1	... ...	... ...	,,
θ	054	57 39	90 0	58 0	90 0	1	... ...	... ...	,,
ξ	411	*	27 23½	63 7½	28 0	1	62 55—63 15	... ...	,,
ζ	522	,,	39 39½	,, ,,	40 0	1	,, ,,	... ...	,,
ω	211	,,	46 1	,, ,,	46 9	5	,, ,,	45 27—46 45	Small; images fair.
i	322	,,	54 6	,, ,,	54 9	10	,, ,,	53 57—54 20	,, ,,
o	111	,,	64 14½	,, ,,	64 17	6	,, ,,	64 9—64 28	,, ,,
ψ	344	,,	70 6½	,, ,,	70 30	1	,, ,,	... ...	Minute.
u	122	,,	76 26	,, ,,	76 31½	18	,, ,,	76 20—76 58	Large; images good.
χ	144	,,	83 7	,, ,,	82 45	1	,, ,,	... ...	Minute.
e	011	,,	90 0	,, ,,	90 0	7	,, ,,	... 90 4	Large; images fair.
ϖ	124	75 47	82 32	75 45	82 25	1	... ...	... ...	Small.
η	012	,, ,,	90 0	76 0	90 10	1	... ...	... ...	Minute.
κ	013	80 25	90 0	80 10	90 0	1	... ...	... ...	,,
λ	901	90 0	11 36	90 0	11 37	2	... 90 11	11 30, 11 44	,,
π	401	,, ,,	24 48½	,, ,,	25 9	3	... ,,	24 40—25 28	,,
τ	301	,, ,,	31 38½	,, ,,	31 35	6	... ,,	31 0—31 53	Small.
Π	502	,, ,,	36 29	,, ,,	36 48	1	... ,,	... ...	Minute.
ρ	201	,, ,,	42 45	,, ,,	42 41	4	... ,,	42 20—42 55	Small.
$\hbar$	101	,, ,,	61 35½	,, ,,	61 35	10	... ,,	61 23—61 50	Minute.
g	102	,, ,,	74 52	,, ,,	75 20	2	... ,,	75 15, 75 35	,,
μ	104	,, ,,	82 18	,, ,,	82 36	1	... ,,	... ...	,,
c	001	,, ,,	90 0	,, ,,	90 0	5	... ,,	... 90 3	Large; image good.

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Mineralogical notes on Western Australian Tellurides: the non-existence of 'Kalgoorlite' and 'Coolgardite' as mineral species.

By L. J. Spencer, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read June 10, 1902.]

SINCE the occurrence of tellurides of gold in Western Australia was first recognized by Mr. Arthur G. Holroyd[1] in May, 1896, these minerals have proved to be of the greatest importance as a source of gold; and in fact the telluride mines at Kalgoorlie in the East Coolgardie gold-field now yield as much gold as all the remaining gold-fields of Western Australia taken together.

Although the occurrence of traces of telluride of gold has been reported from one or two other localities in the neighbouring portions of Western Australia, it is only in a quite small area around Kalgoorlie that the tellurides are mined. Here they occur as lodes, or rather as large lenticular masses and as impregnations, in schistose rocks. It is only, however, below a certain depth that the tellurides are found; nearer the surface, where the rocks have been weathered and altered, these minerals have been decomposed with the separation of native gold.

The tellurides occur in irregularly bounded crystalline masses, and unfortunately appear never to have been found as crystals with plane surfaces. The discovery of such crystals would be full of interest from a scientific point of view, and would afford a solution of many problems, which must, for the present, be left undecided. With the occurrence of such large crystalline masses of tellurides there can be little doubt but that one day crystals will be found; and these will probably surpass those hitherto obtained from other parts of the world. Cavities in the ore appear to be only rarely present, and when these are met with they should be searched for crystals.

[1] For references to original papers see p. 289 below.

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In the present paper are given the results of a purely mineralogical examination of the specimens of Western Australian tellurides preserved in the mineral collection of the British Museum. In this collection there are 129 samples of gold-ores and auriferous specimens from Western Australia, of which sixty-five came from Kalgoorlie; tellurides[1] are present on forty-eight of the Kalgoorlie specimens, which have been acquired at various times since 1897. I have also had opportunities of inspecting many other specimens of Western Australian tellurides at the London offices of some of the gold-mining companies and at the Colonial Exhibition in London in 1902, but have seen nothing essentially different from the British Museum specimens to be described below.

The whole of this rich material, with the exception of only two specimens, has been presented to the Trustees by the several gold-mining companies, by the Government of Western Australia, through the Royal Commission appointed for the exhibition of the products of that State, and by various private individuals. Many of the specimens thus made available for examination by the generosity of the various donors are of considerable intrinsic value. A large proportion of this material had been specially collected by Mr. A. G. Holroyd, the Mineral Curator of the exhibits, for the Paris Exhibition of 1900; previous to this it had been shown at the Coolgardie Exhibition of 1899, and subsequently at the Glasgow Exhibition of 1901, and at a small Colonial Exhibition at the Royal Exchange in London in 1902. At the close of the last exhibition an immense amount of valuable material, including numerous large, showy masses of native gold and gold telluride, was sent by the owners to be converted into bullion. In 1900, Mr. L. Fletcher, F.R.S., Keeper of Minerals in the British Museum, after inspecting the mineral specimens at the Paris Exhibition, called the attention of Mr. Holroyd and of the exhibiting companies to the importance to science of the permanent preservation of specimens illustrative of the modes of occurrence of gold in Western Australia, and as a result was promised, for the British Museum, the gift of various specimens as soon as they should be no longer required by the companies for the purpose of exhibition. In 1902, during the last days of the Colonial Exhibition in London, Mr. Fletcher personally interviewed the

[1] Besides the Kalgoorlie tellurides, there are specimens of tetradymite (bismuth telluride) with native gold in white quartz from the Dunallan No. 1 gold-mine near Coolgardie in the Coolgardie gold-field, which were presented to the Museum by Mr. A. O. Watkins in 1895.

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Hon. H. W. Venn, President of the above-mentioned Royal Commission, and the Hon. H. B. Lefroy, Agent-General for Western Australia and formerly Minister of Mines, and enlisted the active sympathy of both; a large series of specimens, enthusiastically selected by Mr. Holroyd, who was familiar with their peculiarities, was thus saved from destruction, and was presented by the owners to the Trustees of the British Museum.

Calaverite. This is the most abundant and the richest in gold of all the tellurides, and was also the first to be discovered at Kalgoorlie. It is easily recognizable by its pale bronze-yellow colour with bright metallic lustre, and its sub-conchoidal fracture with absence of cleavage. It somewhat resembles iron-pyrites in appearance, and in fact some of the material found by Mr. Holroyd in 1896 had actually been thrown away as such on the waste-heaps.

The mineral occurs sometimes in masses of considerable size, as is shown by a very large specimen (No. 86066) in the British Museum. This mass, from the Associated Gold Mines of Western Australia, is said to be the largest that has been raised. With the matrix of greenish schist it weighs 180 pounds, and over the whole of one surface, measuring about 63×18 cm. (25×7 inches), there is a thick deposit of various tellurides; the calaverite, however, predominates in amount, being in one place continuous over an area of 40×15 cm.

When calaverite is heated on charcoal in the oxidizing flame of the blowpipe, the tellurium it contains is readily oxidized, giving rise to dense white fumes and imparting a bright bluish-green colour to the flame, a bead of gold being left behind. When heated in a bulb-tube, calaverite gives a black sublimate of metallic tellurium, and a less volatile sublimate of drops of tellurous oxide (TeO_2), which is yellow when hot and white or colourless when cold; a yellow malleable bead of gold is not obtained in this way. During the cooling of the beads so obtained, either on charcoal or in the bulb-tube, the interesting phenomenon of *recalescence* was sometimes observed—after a red-hot bead had become dark it suddenly and momentarily again flashed out red and glowing. This behaviour, which was also exhibited by beads obtained from sylvanite, appeared to depend on the presence of a small amount of tellurium still remaining in the bead.

Several chemical analyses have been made of the calaverite from Kalgoorlie, and these, for convenience of reference and comparison, are collected together below. The calculated percentage composition corresponding to the formula $AuTe_2$ is given at the head of the list.

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Analyses of Calaverite from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.	Sp. gr.
$AuTe_2$	56·3	43·7	—		100·0	—
Holroyd (1897) . .	55	44	trace		99	—
,, . . .	54	39·2	3·		96·2	—
Mingaye (Pittman, 1897)	56·65	41·76	0·80		99·21	9·377
Simpson (1898) . .	57·27	41·37	0·58		99·22	9·311
Rogers (quoted by Simpson, 1898) . . .	59·69	38·70	1·66	Cu, 0·21; Fe, 0·18; S, 0·09; Pb, Bi, Zn, traces.	100·53	—
Klüss (Krusch, 1901) .	58·63	37·54	2·06	Cu, 0·29; Fe, 0·09; Ni, 0·07; Se, 1·13; S, 0·10; gangue, 0·23.	100·14	—
Carnot (1901) . .	60·30	33·90	4·82	Cu, 0·63; Fe, trace .	99·65	—
McGeorge (quoted by Simpson, 1902) . .	54·1	42·6	0·7	Arsenopyrite, 2·4 .	99·8	—
MacIvor (1902) . .	57·00	42·15	0·60		99·75	9·314

Sylvanite. This is of much less frequent occurrence at Kalgoorlie than the other tellurides containing gold. It is recognizable by its silver-white colour with brilliant metallic lustre and its perfect cleavage in one direction. It occurs in masses of some size, much larger than those from Transylvania and Colorado; thus one of the British Museum specimens shows the perfect cleavage uniform in direction through a mass 8 cm. in length, and another mass measures 4½ cm. in a direction perpendicular to the cleavage. These large crystalline individuals show no plane crystal-faces, but sometimes, on their rough, striated exterior, there are unmistakable indications of twinning about a plane perpendicular to the direction of cleavage.

It is, however, to be noted that the silver-white colour and the single perfect cleavage are characters possessed by krennerite as well as by sylvanite. Both minerals are further referable to the same type of chemical formula, namely $(Au,Ag)Te_2$; but while sylvanite appears to be fairly constant in composition, approximating to the formula $AuAgTe_4$, krennerite on the other hand varies considerably, the amount of silver, for example, having been given at 0·46, 5·87, and 19·44 per cent. in different analyses of material from Transylvania and Colorado. It would thus be only possible to distinguish with certainty between these two species when crystals are available for the determination of their symmetry, sylvanite being monoclinic and krennerite orthorhombic.

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The silver-white, cleavable gold and silver telluride of Kalgoorlie may thus be either sylvanite or krennerite, or possibly both. Under the circumstances it appears best, for the present, to refer to it as sylvanite, since krennerite has as yet been found only in minute crystals which are not twinned. Again, the krennerite of Transylvania and Colorado is described as decrepitating violently when heated before the blowpipe: none of the Western Australian material in the British Museum behaves in this way, but fuses readily and quietly.

Attention may be called here to a statement by Mr. E. S. Simpson (1898, p. 48): he mentions 'small rhombic crystals with deep vertical striations of a telluride of gold, perhaps Krennerite,' as being associated with calaverite, coloradoite, and native gold on a specimen from the Kalgurli mine. This observation, if correct, is of some importance, but no mention of it is made by Mr. Simpson (1902) in his collected notes on Kalgoorlie tellurides: moreover, cleavable telluride is also referred by him to calaverite and goldschmidtite [1].

Of the analyses quoted below, three approach the formula $AuAgTe_4$, while the first, in containing much less silver, is quite distinct: for this reason the material analysed by Dr. Frenzel has been referred by Professor Hintze [2] to krennerite.

Analyses of Sylvanite (and Krennerite?) from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.	Sp. gr.
$AuAgTe_4$	62·5	24·2	13·3		100·0	—
Frenzel (1897) . .	58·63	36·60	3·82		99·05	8·14
Wölbling (Krusch, 1901)	60·88	28·55	9·76	Cu, 0·32; Fe, 0·06; Ni, 0·10; Se, 0·20; S, 0·09; gangue, 0·05.	99·96	—
Carnot (1901) . .	60·45	29·85	9·18	Cu, 0·15; Ni, 0·10 .	99·73	—
Higgin (quoted by Simpson, 1902) . . .	54·50	36·95	8·30		99·75	—

Petzite. This is readily distinguished from the other gold and silver tellurides by its iron-black colour with metallic lustre and the marked conchoidal fracture with absence of cleavage. It is, however, absolutely indistinguishable in appearance from the mercury telluride, coloradoite;

[1] Goldschmidtite was described in 1899 as a gold and silver telluride from Colorado, but was proved the following year to be identical with sylvanite.

[2] Handbuch der Mineralogie, 1901, vol. i, p. 898.

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and it also resembles more or less closely another Kalgoorlie mineral to be mentioned below, namely, fahlerz.

When heated on charcoal in the oxidizing flame of the blowpipe, petzite produces only slightly the bluish-green colouration of the flame and the dense white fumes characteristic of tellurium; only when fused with sodium carbonate does it give a white malleable bead, and this when placed in nitric acid becomes yellow. Calaverite and sylvanite, on the other hand, are much less stable, and are readily converted into a bead of gold by simply heating on charcoal in the oxidizing flame; this, however, takes place much more readily with calaverite than with sylvanite, since the latter contains more silver in combination with the tellurium.

The analyses quoted below agree closely, like the analyses of petzite from other localities, with the formula $(Ag,Au)_2Te$, in which $Ag : Au = 3 : 1$; the formula may therefore be written as $3Ag_2Te . Au_2Te$ or Ag_3AuTe_2.

Analyses of Petzite from Kalgoorlie.

Analyst.	Te.	Au.	Ag.		Total.
Ag_3AuTe_2	32·8	25·4	41·8		100·0
Wölbling (Krusch, 1901)	32·60	24·33	40·70	Cu, 0·10; Fe, 0·07; Ni, 0·08; Se, 1·45; S, 0·26; gangue, 0·12.	99·71
Carnot (1901) . .	31·58	23·58	43·31	Hg, 0·88; Cu, 0·20; Fe, trace; Sb, 0·30.	99·85
„	32·33	24·16	41·22	Hg, 2·00; Cu, 0·10 . .	99·81
„	33·00	23·42	41·37	Hg, 2·26; Cu, 0·16 . .	100·21
Grace (quoted by Rickard, 1901) . . .	34·60	24·64	40·47	Hg, 0·29	100·00
„ „	34·83	24·62	40·55		100·00

The mercury shown in these analyses, especially in two by Professor Carnot, is no doubt due to the presence of coloradoite as an impurity (cf. p. 284).

Two other analyses, not quoted above, of gold and silver telluride from Kalgoorlie are given by Dr. Krusch[1] and by Professor Carnot[2]. The formulae corresponding to these analyses may be split up as follows:—

$$(1)\quad (Ag,Au)_5Te_3 = 2\tfrac{1}{3}(Ag,Au)_2Te + \tfrac{1}{3}(Au,Ag)Te_2,$$
$$(2)\quad (Ag,Au)_4Te_3 = 1\tfrac{2}{3}(Ag,Au)_2Te + \tfrac{2}{3}(Au,Ag)Te_2,$$

	Te.	Au.	Ag.	Hg.	Cu.	Fe.	Ni.	Zn.	Sb.	S.	Gangue.	Total.
[1]	36·90	15·06	45·95	—	1·16	0·08	0·06	0·04	0·12	0·45	0·22	100·04
[2]	41·11	26·10	30·43	0·70	0·60	0·40	—	—	0·80	—	—	100·14

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suggesting that the substances analysed were probably mixtures of petzite and calaverite. It should be noted, however, that the percentage of silver given by Dr. Krusch is higher than in any of the petzite analyses quoted above, and this may indicate the presence of hessite (see p. 282). Professor Carnot himself suggests that the material he analysed was a mixture.

All these analyses of Western Australian tellurides have of necessity been made on massive material, and in no case does it appear that special precautions were taken to collect pure material all of one kind. Accurate analyses of carefully selected and measured crystals are desirable.

It seems probable that in these tellurides the gold and silver do not isomorphously replace each other, as is usually considered to be the case, but that they are present in atomic proportions, as indicated in the formulae adopted above. These formulae may represent double tellurides or possibly simple salts (perhaps tellur-aurates, analogous to sulph-antimonites).

Coloradoite. This telluride of mercury, with its iron-black colour and well-marked conchoidal fracture, is identical in appearance with petzite, from which it can only be distinguished by chemical tests. In fact, it has no doubt previously been mistaken for petzite, and, as will be shown below, a mixture of coloradoite and petzite has been described as a supposed new mineral species under the name 'kalgoorlite.'

Only two of the several authors (Rickard and Simpson) writing on Western Australian tellurides have mentioned coloradoite as being present on the specimens examined by them; and it has been considered to be of rare occurrence. In reality, however, it is comparatively abundant, for of the forty-eight Western Australian telluride specimens in the British Museum, coloradoite is present on twenty-eight.

In the examination of these specimens ninety-nine fragments of coloradoite were separately determined. This can be done very readily and quickly by heating on charcoal before the blowpipe or in a bulb-tube; in each case the reactions are quite distinct from those of petzite (and of fahlerz, which also somewhat resembles coloradoite in appearance). On charcoal the mineral readily fuses and colours the flame bright bluish-green, emits dense white fumes, and in a very short time completely disappears. In the closed tube it fuses with spluttering to a black globule, and gives a sublimate of globules of mercury and a much less volatile sublimate of

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drops of tellurous oxide, the latter being yellow when hot and white or colourless when cold; with a larger fragment of material a black sublimate of metallic tellurium is also obtained.

The only quantitative analysis made on Western Australian coloradoite is by Mr. E. S. Simpson (1899), who obtained the results quoted below. The same author had previously (1898) given the specific gravity of another sample of material as 9·21.

Hg.	Ag.	Au.	Te (by difference).
50·40	0·12	trace	[49·48].

These numbers give the formula Hg_2Te_3, and not HgTe, the accepted formula for coloradoite deduced by Professor F. A. Genth for the Colorado mineral discovered by him in 1877. The material analysed by Professor Genth was, however, very impure, containing admixed quartz, gold, sylvanite, and native tellurium up to nearly 50 per cent.; but the heavier portions obtained by levigation contained more mercury and less tellurium, and approximated more closely to the formula HgTe. The Colorado material was therefore scarcely suitable for establishing the formula of the mineral, while on the other hand the formula proposed by Mr. Simpson is based only on a single mercury determination. It therefore seemed desirable to make a new analysis, especially as a large amount of pure material was available for this purpose.

The specimen (Brit. Mus. No. 85221) chosen from which to collect material for the present analysis was one on which no petzite or fahlerz had been detected. The only other telluride[1] observed is sylvanite, which shows a brilliant cleavage surface several centimetres across, and could not possibly have been confused with the coloradoite. The bright coloradoite shows excellent conchoidal fractures over comparatively large areas, in one case 2 × 2 cm., and in every way seems to be quite pure. The matrix of the specimen, which is from the Great Boulder Main Reef gold-mine at Kalgoorlie, is a green schist interbanded with white granular dolomite; quartz and iron-pyrites are also present.

Three separate lots of material were collected from the same part of this specimen. In detaching material it usually broke up into quite

[1] To be quite accurate, there was afterwards detected a small compact mass, which, from its appearance under the microscope and its behaviour before the blowpipe, probably consists of an intimate intermixture of petzite and sylvanite. This was the single case in which there was any doubt in the determinations. It is here of no moment, since it is quite separate from the coloradoite and could not possibly have been confused with this.

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small fragments. Each of these fragments was examined under a lens on a sheet of white paper and in a good light, being turned about with a needle mounted in a handle. Each fragment on which the bright conchoidal fracture was interrupted was then separately picked up and again examined under a microscope, the one-inch objective of which is fitted with a lieberkuhn. Further, of the material so collected, twenty-one fragments were examined by heating on charcoal or in a bulb-tube to make certain that no petzite was present and that all was coloradoite.

The coloradoite so collected for analysis was of an iron-black colour with bright metallic lustre, and was quite opaque. It had an excellent conchoidal fracture with no indication of cleavage. The streak was black and shining. The mineral was rather brittle, but extremely friable. Hardness, 2½. The specific gravity was determined with a 3 c.c. pycnometer on the three lots of material with the following results (reduced to water at 4°C.):—

	Sp. gr.	Weight of material used.
	8·074	2·0505 gram.
	8·077	1·7032 „
	8·062	1·2911 „
Mean	8·07	

This result differs considerably from previous determinations. Mr. Simpson gives for the Kalgoorlie coloradoite the value 9·21; and Professor Genth gives 8·627 for the Colorado mineral after allowing for the large amount of impurities present.

The following are the results of one complete, and one incomplete, analysis, together with the calculated percentage composition corresponding to the formula HgTe:—

	I.	II.	HgTe.
Hg	60·95	59·4	61·2
Te	39·38	35·8	38·8
	100·33		100·0

In analysis I, 1·2833 gram of powdered material was decomposed with nitric acid; the decomposition took place readily and completely, and after expelling nitric acid, the residue was completely soluble in water and hydrochloric acid; gold and silver were therefore absent. The sulphides, precipitated by hydrogen sulphide, were separated by digestion with hot, yellow ammonium sulphide, and the insoluble mercury sulphide dried at 100°C. (HgS, 0·9074 gram). The tellurium

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was precipitated in the metallic state from a boiling hydrochloric acid solution by ammonium bisulphite and dried at 100°C. (Te, 0·5054 gram).

These results are confirmed by another analysis previously made, in which more direct determinations were attempted. The behaviour of the mineral when heated in a bulb-tube suggested that, if heated in a combustion-tube in a current of air, metallic mercury and tellurium dioxide could be weighed separately. Under these conditions, however, the tellurium was not completely oxidized, and part of it volatilized with the mercury. The same also happened when the mineral was heated with sodium carbonate. The powdered material (anal. II, 2·1091 grams) was therefore mixed with a little potassium nitrate and an excess of sodium carbonate and heated in a combustion-tube, at the closed end of which sodium bicarbonate had been placed to expel the last traces of mercury. A globule of mercury (Hg, 1·2536 gram) was collected under water; as, however, some nitrous fumes were evolved, the mercury was slightly attacked in the cool part of the tube. The residue in the tube was dissolved in hydrochloric acid and the tellurium precipitated by ammonium bisulphite (Te, 0·7546 gram), but it was afterwards found that the precipitation was not quite complete.

These analyses conclusively prove that the formula of coloradoite is HgTe, and not Hg_2Te_3 as suggested by Mr. Simpson. The formula HgTe is the one to be expected from the relation of coloradoite to metacinnabarite (HgS) and tiemannite (HgSe). These minerals, which resemble coloradoite in their black colour and absence of cleavage, have been found as tetrahedral-cubic crystals, and it is probable that crystals of coloradoite when met with will be found to have the same symmetry. As shown in the following table there is an anomaly, for which no explanation can be given, presented by the specific gravity of this group of isomorphous minerals, the specific gravity of coloradoite being less than that of tiemannite, instead of greater, as is to be expected.

	Formula.	Crystal-class.	Sp. gr.
Metacinnabarite.	HgS	Tetrahedral-cubic	7·81 (Penfield)
Tiemannite . .	HgSe	Ditto	8·19 ,,
Coloradoite . .	HgTe	Ditto ?	8·07

The determinations of Mr. E. S. Simpson, namely, the formula Hg_2Te_3 and sp. gr. = 9·21 (which it must be remembered were not both determined on the same sample of material), led him to consider whether the mercury telluride of Kalgoorlie he examined was identical or not with

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that of Colorado. Though of course it is possible that other mercury tellurides besides coloradoite (HgTe) may occur in nature, it will be best, for the present, to consider all the Kalgoorlie material to be coloradoite, as does Mr. Simpson himself.

Altaite. This mineral, the cubic lead telluride (PbTe), which has not hitherto been recorded from Western Australia, was found in small amount on three of the British Museum specimens, all from the Great Boulder Proprietary gold-mine. It is of a lead-grey colour, sometimes with a yellowish tarnish, and has three perfect cleavages at right angles to each other; measurements of the cleavage angles on the goniometer gave approximately 90°. In appearance it resembles galena, but qualitative chemical tests, both before the blowpipe and in the wet way, proved the presence of lead and tellurium and the absence of sulphur.

It may be useful to place on record, in the following table, the various tellurides which were found more closely associated together, i.e. on the same specimen, and the several mines from which they come. This table is, however, only complete so far as concerns specimens now preserved in the British Museum collection.

Of these forty-eight specimens, calaverite is present on twenty-nine, sylvanite on ten, petzite on fourteen, coloradoite on twenty-eight, and altaite on only three. More than one kind of telluride is shown by twenty-five of the specimens, and on eleven there are three kinds.

The minerals found in association with the tellurides on the British Museum specimens now remain to be briefly described.

Gold. Native gold is more abundant in the upper, oxidized portions of the lodes, having here resulted by the decomposition of the tellurides. This secondary gold is present in a finely divided state: when in loose, finely crystallized aggregates it is known as 'sponge-gold'; when dull and lustreless, with quite the appearance of yellow ochre, it is known as 'mustard-gold'; and when in bright films as 'paint-gold.' A large quantity, about 70 pounds, of specially fine and pure 'sponge-gold' was found in a single pocket in the Great Boulder Proprietary gold-mine; this consists of a cellular aggregate of minute crystals of gold, which, when examined under the microscope, appear to be cubo-octahedra.

Films of secondary gold are also present on one or two of the telluride specimens; but most of the native gold which occurs actually intermixed with the tellurides appears to be of primary origin and to have been deposited at the same time as the tellurides themselves. This

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Specimen No. (Brit. Mus.).	Gold-mine at Kalgoorlie, W. A.	Calaverite.	Sylvanite.	Petzite.	Coloradoite.	Other minerals present.
83433	(Not stated) . . .	×			×	(Quartz, iron-pyrites, sericite, chlorite, and dolomite on most specimens.)
83636 *a*	Lake View Consols . .	×				
83636 *b*	,, ,, . .	×				
83637	,, ,, . .		×			
83638	,, ,, . .	×				
83639	,, ,, . .	×				} Films of secondary gold.
83640	,, ,, . .	×	×			
86002	,, ,, . .		×			
85932	Hannan's Block 45 . .	×				Calcite.
85217	Great Boulder Main Reef		×			
85218	,, ,,		×			Fahlerz.
85219	,, ,,		×		×	Fahlerz.
85220	,, ,,		×	×		
85221	,, ,,		×		×	
85980	,, ,,	×		×	×	
85344	Great Boulder Proprietary	×		×		
85345	,, ,,				×	Gold.
85958	,, ,,				×	
85959	,, ,,	×			×	
85960	,, ,,	×			×	Gold.
85961	,, ,,				×	Gold.
85962	,, ,,				×	Gold.
85963	,, ,,	×			×	Altaite.
85964	,, ,,	×				
85965	,, ,,			×		
85967	,, ,,	×		×	×	
85969	,, ,,	×			×	
85970	,, ,,	×			×	
85971	,, ,,	×		×	×	
85972	,, ,,	×		×		Altaite.
85973	,, ,,	×			×	Altaite.
85974	Great Boulder Perseverance				×	{ Chalcopyrite. { Gold.
85977	,, ,,				×	Gold.
85978	,, ,,				×	Gold.
85979	,, ,,	×	×	×		
85981	Associated Gold Mines, W.A.	×			×	Gypsum.
85983	,, ,,		×		×	
86066	,, ,,	×		×	×	Fahlerz.
85984	Associated Northern Blocks			×		Gold.
85985	,, ,,	×				Gold.
85991	Ivanhoe Gold Corporation	×				Chalcopyrite.
85993	Golden Horse-Shoe Estates	×		×	×	Gold
85994	Brown Hill Extended .	×			×	
85995	,, ,,	×			×	Tourmaline.
85996	Hannan's Brown Hill .			×		{ Tourmaline. { Brown-spar.
86000	Hannan's Star . .				×	Gold.
86008	South Kalgurli . .	×		×	×	Magnetite.
86009	,, . .	×		×	×	Fahlerz.

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primary gold is present in thicker and more lumpy masses than the finely divided secondary gold.

Fahlerz. This somewhat closely resembles the petzite and coloradoite in appearance; it has the same conchoidal fracture, but the iron-black colour is rather darker and often somewhat dull on the surface. The streak is black; H. = 4. Qualitative analysis showed the presence of copper, sulphur, and arsenic, with rather less antimony and a little iron and zinc. Small patches of the massive mineral were found on four of the telluride specimens.

This is without doubt the same mineral as the copper-ore noted by Dr. Krusch (1901, p. 202, footnote), for which he gives no name, but states that the composition is near that of enargite. From the analysis he gives, I have deduced the fahlerz formula [1]—

$$[3R'_2S \cdot R'''_2S_3] + \tfrac{1}{5}[6R''S \cdot R'''_2S_3].$$

This formula partly accounts for the excess of sulphur, which is, in any case, much less than that required by the enargite formula. The analysis shows the presence of 16·87 per cent. of arsenic and 4·30 per cent. of antimony, so that the mineral is nearer to tennantite than to tetrahedrite.

Magnetite. Three or four crystals, each measuring about a centimetre across, were found embedded in the tellurides on a single specimen from the Kalgurli mine. They are iron-black with a bright metallic lustre, and are strongly magnetic. The small faces present on one crystal were determined on the goniometer to be those of the octahedron and rhombic dodecahedron. The crystals are remarkable in possessing perfect parting-planes parallel to the faces of the octahedron. From the surfaces of parting are often to be seen deep-red flashes of reflected light; and when a piece of the mineral is crushed and examined under the microscope many fragments are seen to be blood-red by transmitted light and to be doubly refracting. The streak of the mineral is dark purplish-brown, but that of the portion of the powder attracted by a magnet is black. In these crystals there has therefore been a partial alteration along the parting-planes of the magnetite to hematite, and they really represent a stage in the formation of *martite.*

Calcite appears to be present on only one specimen, this being a portion of the original material from Hannan's Block 45, discovered by Mr. Holroyd in 1896. It has the character of a white crystalline limestone, in which the calaverite is embedded. *Dolomite,* on the other

[1] Compare this Magazine, 1899, vol. xii, p. 202.

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hand, is present on most specimens; it usually forms grey, compact bands interfoliated in the greenish schist. On one specimen are cleavable masses of *brown-spar* (probably mesitite).

Tourmaline occurs as small black needles, 2 to 3 mm. in length, embedded in iron-pyrites and in the rock. It has a specific gravity of about 3·2, and the dichroic colours vary from quite black to nearly colourless. A very little *chalcopyrite* is enclosed in coloradoite on one specimen; on another it is represented by a mere speck in quartz. Veins of fibrous *gypsum* penetrate the altered rock of one specimen.

The matrix[1] of the telluride specimens is usually a pale greenish **sericite-schist** with a silvery reflection, and soft enough to be scratched by the finger-nail. Minute grains and crystals, usually cubes, of *iron-pyrites* are scattered throughout the whole rock. *Chlorite* is also often present, and the rock is then of a darker green colour, and may approach a chlorite-schist in character. Interfoliated with the schist are often bands of grey, granular dolomite, so that at times the rock has rather the character of a calc-schist. Patches of massive, colourless *quartz* and of finely granular iron-pyrites are sometimes present, especially in close association with the tellurides, though not in very large amounts. The tellurides are embedded in the schist as irregular masses of variable size, and often follow joint-planes oblique to the schistosity; the rock appears never to be finely impregnated with tellurides as it is with iron-pyrites.

A more detailed examination was made of the rock of the large specimen (No. 86066). A thin section, perpendicular to the schistosity, showed under the microscope much *sericite* and a considerable amount of quartz. The quartz is present as fairly large, irregular individuals, usually with a more or less marked undulose extinction, and also as patches of mosaic. Much iron-pyrites is present as small grains; only one speck of black telluride was to be seen. There are also many irregular patches of *ilmenite*, which shows well-marked planes of parting and has been largely altered to 'leucoxene.' These small masses of ilmenite give rise to a knotted appearance on the surfaces of foliation as seen in a hand-specimen of the schist. A chemical examination of the

[1] The matrix of the ore is often stated to be hornblende-schist. No hornblende was detected on any of the British Museum specimens; and in published analyses (Simpson, 1902) of these rocks the small amount of magnesia in the portion of the rock insoluble in hydrochloric acid indicates that not much, if any, hornblende can be present. Bands of hornblende-schist are no doubt sometimes present in the sericite-schist. Much confusion between observed fact and theory has been occasioned by the attempts of various authors to explain the origin of these schists.

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rock showed the presence of silica, alumina, iron, alkalies (potash and soda), and a little lime; when heated in a bulb-tube it blackens and gives off scarcely any water. The ilmenite was proved to contain iron and titanium, and to be non-magnetic.

The altered rocks from the upper portions of the lodes are soft and clayey and yellow in colour, but they usually still retain their schistose character. Besides *limonite* and the finely divided secondary gold, few other minerals are found in these oxidized ores. On one specimen, from the Golden Horse-Shoe Estates, the 'sponge-gold' is accompanied by a few small colourless rhombohedra of dolomite, and a yellowish-green ochreous substance which is perhaps massicot (PbO)[1].

With the alteration of such large quantities of tellurides one would expect to find other secondary minerals together with the native gold, such, for example, as native silver (from the petzite) and oxygen compounds of tellurium (tellurite (TeO_2), emmonsite, durdenite, &c.), but none of these were detected[2] on the British Museum specimens. Mr. Simpson (1898, p. 46) suggests the occurrence of emmonsite (hydrated ferric tellurite), and Mr. Rickard (1901, p. 712) mentions the presence of tellurite of iron on a specimen from Kalgoorlie. Silver chloride is stated to have been found in considerable quantity near the surface in one of the mines (Pittman, 1898, p. 11).

Other minerals, which have been described as occurring with the Kalgoorlie tellurides, but which were not detected on the British Museum specimens, are native tellurium (Holroyd, 1897; MacIvor, 1900) and roscoelite (Pearce, 1897). Hessite (Schmeisser, 1897, p. 50; Krusch, 1901), amalgam (Pittman, 1898), and native mercury (Rickard, 1901, p. 715) have also been mentioned; and Simpson gives several other names in his lists of minerals, but without particulars.

'Kalgoorlite' and 'Coolgardite.'

'Kalgoorlite' was described by Mr. E. F. Pittman in 1898 as a new mineral species with an iron-black colour and sub-conchoidal fracture, a specific gravity of 8·791, and a chemical composition expressed by the formula $HgAu_2Ag_6Te_6$. The analysis, by Mr. J. C. H. Mingaye, from which this formula was deduced, is quoted below. The material on

[1] A chemical examination showed the presence of much lead, with a little copper and water, and possibly some antimony.

[2] It is possible that some of the yellowish earthy material, taken to be limonite, may contain tellurium in the oxidized state, but none of this was examined chemically.

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which the new name was based came from the Lake View and Boulder Junction gold-mine at Kalgoorlie. Recently Mr. E. S. Simpson (1902) states that in 'a sample from the Ivanhoe Mine' he found gold 19·4, silver 30·1 per cent.

'Coolgardite' was based by Professor Adolphe Carnot in 1901 on the results of three analyses, from which he deduced the formula $(Au,Ag,Hg,Cu,Fe,Sb)_2Te_3$, or more simply $(Au,Ag,Hg)_2Te_3$; the new mineral being defined as a sesquitelluride of gold, silver, and mercury. The material he examined was supplied for analysis by Mr. A. G. Holroyd from the Western Australian exhibits at the Paris Exhibition of 1900; it consisted of fragments, isolated from the matrix and contained in six tubes, all of which, with the exception of one tube of sylvanite, were labelled as being from the Great Boulder Proprietary gold-mine at Kalgoorlie. Professor Carnot remarks that the material contained in each tube was not always the same in appearance and colour, but adds that he took the precaution of separating the different kinds when the quantity of material available for analysis permitted. He further remarks that the material contained in each tube may have been taken from different specimens. In addition to 'coolgardite' he made analyses, quoted above, of sylvanite, calaverite, and petzite.

Two analyses (Nos. 1 and 2 in the following table) of 'coolgardite' were made on material belonging to the same lot. This is described as only exceptionally showing indications of cleavage, the fracture being almost always conchoidal: the colour of the different fragments was iron-grey, or yellowish-grey inclining to bronze; separate analyses were therefore made of two fragments. Another analysis (No. 3) was made on a sample of material described as yellowish-grey with a conchoidal fracture.

		Te.	Au.	Ag.	Hg.	Cu.			Total.
'Kalgoorlite'		[37.26]	20.72	30.98	10.86	0.05; S, 0.13.			100.00
							Fe.	Sb.	
'Coolgardite'	(1)	56.55	23.15	16.65	3.10	0.10	trace	0.20	99.75
,,	(2)	53.70	27.75	13.60	3.70	0.25	trace	0.15	99.15
,,	(3)	51.13	37.06	4.71	3.70	0.88	0.90	1.20	99.58

That 'kalgoorlite' is not a homogeneous mineral, but a mixture, has already been suggested by Mr. T. A. Rickard (1901, p. 715), who with reference to it remarks: 'As the crystallographic features [i. e. external characters] do not differ materially from coloradoite, it can hardly be considered as more than an impure variety of the latter, and may be looked

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upon as a mixture of petzite and coloradoite.' Again, Professor Carnot applies the name 'kalgoorlite' to a 'mercurial petzite,' of which he gives three analyses (quoted above, under petzite); the 'kalgoorlite' of Carnot is, however, considerably different in composition from the 'kalgoorlite' of Pittman, and this adds support to Rickard's suggestion.

A fact that strikes one as being specially remarkable is that neither Mr. Pittman nor Professor Carnot, both of whom describe more than one kind of telluride, makes any mention of coloradoite. This telluride of mercury is, as noted above, of frequent occurrence at Kalgoorlie, and, furthermore, had been found there before the descriptions of 'kalgoorlite' and 'coolgardite' were published: it was recognized by Mr. T. A. Rickard in 1897, and in the same year a specimen showing calaverite and coloradoite was represented in the British Museum collection. This is a point of special importance, since it is impossible to distinguish between coloradoite and petzite by their appearance alone. It would be extremely difficult, if not impossible, to collect pure material for analysis from a mixture of these two minerals, even when it is known that both are present; and in case the presence of coloradoite was not suspected, and not tested for, it would of course be quite overlooked. It is therefore highly probable that the mercury shown in the analyses of 'kalgoorlite' and 'coolgardite' was due to the presence of coloradoite.

Even a study of the original papers themselves suggests that 'kalgoorlite' and 'coolgardite' cannot be distinct mineral species. A massive mineral, which in a single analysis gives, like 'kalgoorlite,' an unusual and complex formula, has, in most cases, little claim to rank as a distinct species, and absolutely none when its composition can be just as well, or even better, explained on the assumption that the material analysed was a mixture of known minerals. Mineralogical literature is unfortunately heavily burdened with numerous imperfectly and incompletely determined 'new species' of this kind.

The formula of 'kalgoorlite' may be split up as follows:—

$$HgAu_2Ag_6Te_6 = HgTe + 2Ag_3AuTe_2 + Te.$$
('Kalgoorlite') (Coloradoite) (Petzite)

The atomic ratio, 3:1, of silver to gold is exactly that given by all analyses of petzite. The excess of tellurium scarcely needs explanation, since this element was not determined directly in the analysis, but only by difference.

The wide variations in the three analyses of 'coolgardite' are in themselves enough to suggest that the material analysed was not homogeneous;

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and this impression is amply supported by the brief description Professor Carnot gives of the external characters of his material. As pointed out above (p. 273), the material used in three other of Carnot's analyses was very probably not homogeneous, and in one case this is even admitted by Carnot himself. A point which is perhaps in favour of the existence of 'coolgardite' is the fact that the results obtained in three separate analyses can, on the assumption of isomorphous mixing, be all made to agree more or less closely with one general formula: the calculated[1] atomic ratios of (Au,Ag,Hg) : Te are 1 : 1·551, 1 : 1·483, and 1 : 1·610 in the three analyses respectively.

The empirical formulae corresponding to Carnot's analyses are:—

(1) $HgAg_{10}Au_{7.6}Te_{23.8}$.
(2) $HgAg_{6.8}Au_{7.6}Te_{22.9}$.
(3) $HgAg_{2.4}Au_{10.2}Te_{21.8}$.

These, by solving simultaneous equations, may be split up as follows:—

(1) $HgTe + 1{\cdot}23\,Ag_3AuTe_2 + 0{\cdot}07\,AuTe_2 + 6{\cdot}3\,AuAgTe_4$.
(2) $HgTe + 1{\cdot}15\,Ag_3AuTe_2 + 3{\cdot}1\,AuTe_2 + 3{\cdot}35\,AuAgTe_4$.
(3) $HgTe + 0{\cdot}78\,Ag_3AuTe_2 + 9{\cdot}27\,AuTe_2 + 0{\cdot}2\,AuAgTe_4$.
(Coloradoite) (Petzite) (Calaverite) (Sylvanite)

The third analysis would thus appear to have been made on material consisting mainly of calaverite; and this is in agreement with Carnot's statement that the material was yellowish-grey with a conchoidal fracture. In the first two analyses more of the iron-black tellurides and more sylvanite would be present, and in No. 1 practically no calaverite; this, again, is in agreement with Carnot's statement of the external characters of the material, which he describes as varying in colour from iron-grey to yellowish-grey, and usually with a conchoidal fracture, but sometimes a cleavage. Although not stated by Carnot, it would appear that analysis No. 2 was made on a yellower fragment. The difference in colour is explained by Carnot as due to the difference in the relative proportions of gold and silver shown in the analyses, but this is scarcely likely to be the case. Of special importance is the fact that Carnot made no serious attempt to separate the black from the yellow, for, as he distinctly states in his paper, he simply took for each analysis

[1] The small amounts of antimony, copper, and iron, calculated by Carnot with the metals, are here neglected, as it seems doubtful whether the antimony should be taken with the tellurium or with the gold; it is not unlikely that they are impurities due to the presence of fahlerz. The atomic weights used here and elsewhere in the present paper are those recommended in 1901 by the Atomic-Weight Commission of the German Chemical Society.

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(Nos. 1 and 2) only *one* piece of material. It would be extremely unlikely, under the circumstances, for such material to be pure and all of one kind.

I have been informed by Mr. F. T. Trouton, the assistant curator of the Western Australian exhibits at Paris, &c., that the material supplied to Professor Carnot for analysis consisted of fragments which had become detached from various specimens. It is thus not unlikely that some of Carnot's material was actually from specimens now in the British Museum. I have myself collected such a tube of fragments, which, owing to the extremely friable nature of the tellurides, have become detached during the transportation and handling of the specimens. From such a collection of fragments of all kinds and from several specimens it would not be at all easy to collect material suitable for analysis. The sylvanite, if coarsely crystallized, could no doubt be easily picked out, but not so easily calaverite from coloradoite and petzite; these are sometimes associated together in the same fragment, and it is only with difficulty that the actual junction of the calaverite with the iron-black mineral can be detected, while the coloradoite and petzite are absolutely indistinguishable.

Although I have had some experience in collecting pure material for analysis, I should be unwilling to deal with such a sample. On this occasion I have given (p. 276 above) more fully the method I adopt for collecting opaque minerals[1] for analysis. Whenever possible, however, only crystals are taken, and these are broken up and each fragment collected separately; and in cases where there can be any possible doubt as to the identity of the mineral, every crystal or crystal fragment is measured on the goniometer. All this of course takes time, and the collection of even less than a gram of material may mean several weeks' work, but it is the only way by which errors are to be avoided. Even with all care and precaution the material may be rendered impure by the presence of an unsuspected mineral, as was undoubtedly the case with coloradoite in 'kalgoorlite' and 'coolgardite.' An exactly similar case has occurred with the material collected by myself for analyses of stannite[2]. On the results of these analyses, especially together with the remarkable development of the crystals, there could have been based a far more plausible 'new mineral' than either 'kalgoorlite' or 'coolgardite.' The analytical results could, however, be explained on

[1] e. g. andorite, argyrodite, fahlerz, plagionite, &c., described in the pages of this Magazine.

[2] This volume, p. 61.

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the assumption that the material used was a mixture of stannite and andorite, and on again examining the part of the specimen from which the material had been collected, this was amply confirmed.

With the object of testing whether these doubts as to the existence of 'kalgoorlite' and 'coolgardite' have really any ground, I have made a detailed examination of all the British Museum specimens of Western Australian tellurides. Although I have not had an opportunity of examining the original material on which the names were based, yet, as noted above, a large amount of the available material came from the same source as did that examined by Professor Carnot, and, indeed, possibly from the same specimens.

Five specimens have at various times been received at the Museum labelled as 'kalgoorlite,' but on whose authority was not stated. On none of these was anything found which answered (except in external characters) to the description of 'kalgoorlite.' On two specimens the only telluride to be found was coloradoite; on another calaverite and coloradoite; on a fourth calaverite and petzite; while on one specimen calaverite, coloradoite, and petzite were all detected, but no other telluride.

The material was examined before the blowpipe in the manner described above. When any mercury was given off in the bulb-tube the mineral was in all cases completely decomposed with the formation of metallic mercury and tellurous oxide; while, when no mercury was given off in the tube, the same fragment afterwards gave a metallic bead on charcoal. Numerous fragments when first heated on the charcoal completely volatilized without leaving the slightest residue. All these fragments were therefore either mercury telluride or gold and silver telluride, and none could have contained all three metals as required by 'kalgoorlite' and 'coolgardite.' These tests, which are reliable and also quickly and readily performed, were made use of for the purpose of distinguishing between the iron-black minerals with conchoidal fracture, namely, coloradoite, petzite (and fahlerz), and also to detect if possible the presence of any 'kalgoorlite' and 'coolgardite.' The fragments tested were detached from the specimens by a needle, and each examined under a lens; only quite small fragments showing the conchoidal fracture uninterruptedly over the whole surface were selected.

In this way 133 fragments[1] of the iron-black tellurides taken from

[1] This includes twenty-one fragments examined to test the purity of the material collected for the qualitative analyses of coloradoite. Of the 112 fragments taken at haphazard, thirty-four were petzite and seventy-eight coloradoite; this gives an idea of the relative frequency of occurrence of these two tellurides.

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different portions of thirty-five specimens were separately examined; of these, thirty-four were found to be petzite and the remainder coloradoite. In addition to these, about thirty fragments of calaverite and sylvanite were examined before the blowpipe. On the forty-eight specimens examined, more than one kind of telluride was found on twenty-five; calaverite and coloradoite were found together on seventeen, and petzite and coloradoite on seven (see table, p. 279).

Petzite and coloradoite being indistinguishable in external appearance, it is possible to take fragments in which both these tellurides are present, and which are to all appearance homogeneous; such fragments will of course be found to contain gold, silver, and mercury, and will thus answer perfectly to the description of 'kalgoorlite.' On these larger fragments, however, the conchoidal fracture was not continuous over the whole surface, indicating that the fragment consisted of more than one crystalline individual of the same kind of mineral, or even (as is actually the case) of different minerals. When, however, small fragments with a continuous conchoidal fracture were taken they were found in *every* case to be either coloradoite or petzite, containing either no gold or no mercury.

After this fairly exhaustive search for 'kalgoorlite,' one is perfectly justified in assuming that no such mineral exists, especially when the single analysis on which the name is based can be simply explained by the intermixture of the two minerals, petzite and coloradoite, which in external appearance are indistinguishable, and which have been shown to actually occur intimately associated together at Kalgoorlie.

While the cause of the error in the case of 'kalgoorlite' is readily explained, it is less easy to believe that such an error could have been committed in the case of 'coolgardite'; for there are marked differences in the external characters of the iron-black tellurides (petzite and coloradoite) and the light-coloured tellurides (calaverite and sylvanite), which must have been present in the mixtures analysed. Professor Carnot indeed notices these differences, but makes no mention of the possibility of the material being a mixture.

There appears to be little to support Professor Carnot's supposition that mercury is capable of isomorphously replacing gold and silver, beyond the fact that these metals, like so many others, crystallize in the cubic system. And it might be suggested that 'coolgardite' is a mixture of coloradoite and a hitherto unknown sesquitelluride of gold and silver, $(Au,Ag)_2Te_3$, as given by Carnot's formula. The ratio (Au,Ag) : Te is then 1 : 1·640, 1 : 1·586, and 1 : 1·739 in the three analyses respectively.

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The excess over 1 : 1·5 could then be readily explained by the admixture of small amounts of the known tellurides, calaverite and sylvanite. This view receives some support from the fact that, on the assumption of a mixture of known tellurides as here adopted, there must have been four different tellurides present in the material used for analysis No. 2[1]. On none of the British Museum specimens were more than three different kinds of tellurides found associated together, and it thus seems unlikely, but not impossible, that there should have been three or four kinds in a single fragment such as is stated by Carnot to have been used in two (Nos. 1 and 2) of his analyses. On the other hand, if several fragments from the miscellaneous sample had been used for analysis, as may have been the case in analysis No. 3, there is less objection to the assumption of a mixture of four different tellurides. Again, in the mixtures suggested above, the amount of sylvanite seems to be excessive; this, however, would be less if the calaverite were assumed to contain some silver, or if hessite be present (cf. pp. 274, 282). The probable existence of an intimate mixture of sylvanite and petzite has been noted above (foot of p. 275).

There thus appears, on the whole, to be no more evidence for the existence of a mineral having the composition $(Au,Ag)_2Te_3$ than for minerals with the compositions $(Au,Ag)_5Te_3$ and $(Au,Ag)_4Te_3$ (see p. 273); and it seems best, for the present at least, to assume that in all these cases the material used for analysis consisted of mixtures of known tellurides.

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[1] The small amount of calaverite in No. 1 is negligible; and in No. 3 there would be no sylvanite if the calaverite contained even a little silver.

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Notes on minerals from the neighbourhood of Binn (Switzerland)—Mispickel, Pyrites, Diopside, and Quartz.

By W. J. Lewis, M.A.

Professor of Mineralogy in the University of Cambridge.

[Read November 18, 1902.]

Mispickel.

CRYSTALS of mispickel are occasionally found in long brilliant tin-white prisms of simple habit in the cavities of the dolomite at Lengenbach, near Binn; but they are more frequent as isolated crystals entirely imbedded in a rather compact mass of the dolomite. The crystals are elongated in the direction of the brachy-axis, and are terminated by two minute faces which give good images and prove to be the faces usually adopted as the prism {110}. The long faces are much striated parallel to their mutual edges of intersection; and the images were consequently so elongated in this zone that only roughly approximate measurements of the angles could be obtained. The brachydomes satisfactorily established were *s* {012} and *l* {011}. On a very minute needle the faces of {021} seem to be associated with *s*{012}, but the angles over homologous edges in which these faces meet the adjacent faces *s* differed by as much as 3°. One crystal seemed to be an elbow-twin with (110) for twin-face, but the angles were not measured.

The angles on which reliance could be placed were on one crystal, $mm' = 68° 50'$, $ll' = 100° 45'$: on a second very minute crystal, $mm' = 68° 50{\cdot}5'$, $ms = 72° 44'$—$73° 27'$, $ss' = 61° 40'$—$62° 34'$. The angles adopted to give the elements are: $mm' = 68° 52{\cdot}5'$, $ms = 72° 55'$; hence $ss' = 62° 36'$ and $ll' = 101° 8'$.

On referring to Miller's table of angles in his edition of Phillips' 'Mineralogy,' 1852, it will be found that his three angular elements are (1) not consistent with one another, and (2) do not accord with the angles given in his table. Miller's two angular elements, $D = 29° 41'$, and $E = 49° 56'$, agree with those adopted by Professor Dana, whilst the third is given as $F = 55° 56{\cdot}5'$ instead of $55° 52{\cdot}5'$ as is required by the relation $\tan D \tan E \tan F = 1$.

Again, in the table we are given $mm' = 68° 48'$, $ll' = 100° 38'$, and $ee' = 120° 48'$; whilst the two angular elements first given above require

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mm' to be 68° 15′, ll' to be 99° 52′, and es' 120° 38′. The three angles given are consistent; for tan 84° 24′ tan 60° 24′ = cot D = tan 50° 19′. It looks therefore as if Miller had computed his table from the given angles, and had then in error copied his elements from another sheet of paper on which other elements had been tried.

Pyrites.

On the crystals of this substance from the Binn dolomite numerous faces are sometimes observed. On one of the crystals measured the following forms were determined: a {100}, $e = \pi$ {210} bright, π {120} rough and ill-developed, o {111}, μ {411}, m {311}, n {211}, β {322}, {544}, $s = \varpi$ {321}.

The angles measured were:

o : (544)	6° 8′ and 6° 45′
$o\beta$	11 25
on	19 28
om	29 27, 29° 7′ and 28° 49′
$o\mu$	35 12
oa	54 43
os	22 21 and 22° 31′
oe	39 7

Diopside.

Some good crystals of diopside of a pistachio-green colour imbedded in quartz are stated to be from mount Cherbadung, and doubtless come from the locality described in Hintze's 'Mineralogie,' vol. ii, p. 1063, as Thierälpeli, Tscherwandune. The crystals are sometimes long rectangular prisms with edges modified and several terminal faces; sometimes the prisms are short and not much larger than some of the faces at the ends. The angles measured accord very closely with those given by vom Rath for augite from Vesuvius. The forms which were observed are: {100}, {310}, {210}, {110}, {130}, {010}, {10$\bar{1}$}, {111}, {221}, {021}, {$\bar{2}$21}, {$\bar{3}$12}, and {$\bar{1}$32}. The faces were for the most part bright and gave very fair images; but the faces of {10$\bar{1}$}, {$\bar{3}$12}, {$\bar{1}$32} were dull, and had much the aspect of a face artificially ground but not polished.

Pericline, Quartz, and Sphene.

In September, 1901, a mineral-seeker from Binn found in the rocks on the south side of the Ofenhorn a cavity which was lined with large

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crystals of pericline and quartz. With considerable labour these were extracted in large specimens, two of which weighed approximately 1 cwt. and ½ cwt. respectively; the larger one is now in the British Museum, the smaller one at Cambridge. The crystals of pericline are of much the usual habit, and are much twinned according to the pericline-law. The faces are bright, but so deeply striated that I have not discovered any crystals which admit of goniometric measurement.

The crystals of quartz are limpid, but occasionally penetrated by and incrusted with chlorite. They are unusually rich in faces which belong more especially to direct rhombohedra and trapezohedra. As observed by Des Cloizeaux in his 'Mémoire sur la cristallisation et la structure intérieure du quartz,' 1858, the faces of the direct forms are bright, fairly free from striæ, and slightly rounded; those of the inverse forms are small and much striated. The faces r {100} and z {$\bar{1}22$} are fairly large and irregularly developed.

The direct rhombohedra observed are: {100}, {18.2.2}, {722}, {311}, {31.$\bar{1}$1.$\bar{1}$1}, {11.4.4}, {522}, {17.7.7}, {733}, and possibly {29.$\bar{1}$0.$\bar{1}$0}, {944}.

The inverse rhombohedra are: {$\bar{1}22$}, {755}, {322}, but the measurements from which the two last symbols were derived were not very trustworthy.

The direct trapezohedra are: u {84$\bar{1}$}, y {10.5.2}, x {42$\bar{1}$}. On two crystals a well-defined image was obtained between those of x and y inclined at 53° 26′ and 53° 42′ respectively to z: this face may be either (22.$\bar{1}$1.5), or (14.7.3). The former makes with z an angle 53° 41·5′, the latter one of 53° 11·5′.

The inverse trapezohedra are: t {11.4.2}, μ {221}, {8.$\bar{1}$0.5}.

The trigonal bipyramid s {421} is also present on most of the crystals, and is striated in a direction parallel to the edges in which it meets faces of the inverse trapezohedra.

The prism faces {2$\bar{1}$1} are usually of considerable length, and the crystals are sometimes doubly terminated.

The crystals of sphene are of the chlorine-green colour common to those which come from the Central Alps, and many of them are twins with (100) for twin-face. Adopting Des Cloizeaux's and Dana's axial system, the forms observed are: {100}, {102}, {001}, {111}, {021}, {310}, {110}, {$\bar{1}$32}, {$\bar{1}$12}. There was nothing exceptional in the crystals or the angles.

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On some new forms prominently developed on crystals of Proustite.

By F. E. E. Lamplough,

Of Trinity College, Cambridge.

[Communicated by Professor W. J. Lewis, and read November 18, 1902.]

WHILST determining some crystals of proustite in the Mineralogical Museum at Cambridge, and which came from Bolivia or some other part of South America, my attention was attracted by faces of trigonal pyramids, which, as shown in figs. 1 and 2, are the most conspicuous on the crystals. On measurement, these faces were found to correspond very nearly to those of the rhombohedra $\{733\} = 10\,R$ (fig. 1) and $\{9\bar{4}\bar{4}\} = 13\,R$ (fig. 2). The figures represent with fair accuracy the

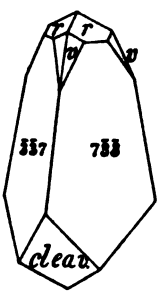

Fig. 1.

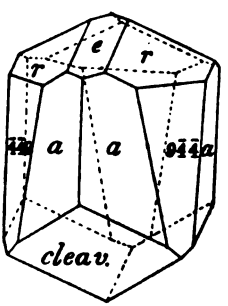

Fig. 2.

Proustite.

relatively large development of the faces of these new forms. Another form, $\{11.7.7\} = -6\,R$, represented by a single face on the lower end of one crystal, is also new for proustite. Ten crystals were measured, and, among these, seven showed the following forms:—

(1) r $\{100\}$, a $\{10\bar{1}\}$, v $\{20\bar{1}\}$, $\{733\}$. (2) r, a, e $\{110\}$, v, $\{733\}$. (3) a, e, $\{9\bar{4}\bar{4}\}$. (5) a, e, $\{9\bar{4}\bar{4}\}$. (7) r, a, e, $\{9\bar{4}\bar{4}\}$. (9) r, e, $\{9\bar{4}\bar{4}\}$. (10) r, e, a, $\{9\bar{4}\bar{4}\}$, $\{11.7.7\}$.

The appended table gives the measurements obtained for the several

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crystals, together with the computed angles[1]. The theoretical value of the angle v : (733) was calculated by the formula given by Professor Lewis in his memoir on Grassmann's method[2].

	Crystal 1.	Crystal 2.	Crystal 3.	Crystal 5.	Crystal 7.	Crystal 9.	Crystal 10.	Observed Means.	No. of Observations.	Computed Angle.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′
(9̄44) : r	...	...	...	...	...	42 30	42 18 42 55	42 34	3	42 24
(733) : r	40 49½ 40 24½ 40 43	40 27 40 35	...	...	...	...	...	40 36	5	40 59
(11.7.7) : r	...	...	...	...	...	...	57 21	57 21	1	57 18·5
re	...	67 44 67 59	...	...	...	67 29	67 36 67 29	67 39½	5	67 46
(9̄44) : e	...	...	109 51	110 18	110 2	109 59	109 54 110 24	110 5	6	110 10
ar	...	...	...	...	53 52	...	54 11	54 1	2	53 54
av	24 53	...	...	...	...	...	...	24 53	1	24 54
ae''	...	...	...	...	90 17	...	...	90 17	1	90 0
vr	29 6½ 29 25	...	...	...	...	...	...	29 16	2	29 20
rr'	72 11	...	...	...	...	...	71 55	72 3	2	72 12
re''	...	...	...	...	85 59	...	85 59 85 56	85 58	3	86 6
ae	...	...	69 20 or 67 59 68 41	68 20	...	...	...	68 30	2	68 37
ee'	...	...	43 5 42 43	43 0	...	...	...	42 56	3	42 46
(733) : v	24 18 24 20	...	...	...	...	...	...	24 19	2	24 25·5
(733) : a	...	80 22	...	...	...	...	...	80 22	1	80 34
(733) : (337)	118 34	...	...	...	...	...	...	118 34	1	118 52
(9̄44) : (101)	...	...	78 28	78 8	78 25	...	...	78 21½	1	78 28

[1] From the element of Prof. Miers, this Magazine, 1888, vol. viii, p. 44.

[2] This Magazine, 1900, vol. xii, p. 339.

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Crystalline forms of Carbides and Silicides of Iron and Manganese (' *Ferro-manganese,*' *&c.*).

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read November 18, 1902.]

MALLARD[1], in 1879, noted that crystals of the metallurgical products 'Spiegeleisen' and 'ferro-manganese' are of two kinds. Both show a prism-zone of six faces, but when the percentage of manganese reaches a certain amount there is an abrupt change in the habit of the crystals and in the angles between their faces. Crystals containing from 11 up to 52 or 55 per cent. of manganese are lamellar, and were found to have a prism-angle ($mm''' = 110 : 1\bar{1}0$) of 67° 27′, while crystals containing a larger amount of manganese are acicular and have a pseudo-hexagonal prism-zone, the angular measurements of which varied between 58° 42′ and 61° 20′.

These observations have been confirmed by Rathke[2] and Brauns. Crystals with the composition given by the analysis quoted below under (1) were found to have a prism-angle[3] of 68° 5′, while crystals with more manganese, as shown in analysis (2), had angles of about 60° in the prism-zone.

	Fe.	Mn.	C.	Si.	P.
(1)	47·93	44·99	6·48	0·52	0·00
(2)	9·48	82·45	7·47	0·18	0·10

These differences in crystalline form are in correspondence with the metallurgical terms 'Spiegeleisen' and 'ferro-manganese'; the former

[1] E. Mallard, Sur la forme cristalline du ferromanganèse. Bull. Soc. Min. de France, 1878, vol. ii, pp. 47–50.

[2] B. Rathke, Ueber krystallisirtes Ferromangan. Liebig's Annalen der Chemie, 1890, vol. cclx, pp. 326–32. [With crystallographic determinations by R. Brauns.]

[3] This angle, 68° 5′, is the mean of readings which varied between 67° 40′ and 68° 30′. It is given by Brauns as the angle *bm*, since it was repeated four times on the same crystal; this repetition may, however, be explained by twinning on a prism-plane.

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has a lamellar crystalline structure and contains less manganese, while the latter has an acicular structure and more manganese.

The absence of terminal faces has prevented previous observers from completely determining the crystals, and it has thus been impossible to state to which crystal-system they belong.

Crystals of two kinds, with prism-angles the same as noted above, and with well-developed terminations, have recently been sent to the British Museum for crystallographic determination by Mr. J. E. Stead, the well-known metallographer. In these crystals, however, the carbon is largely replaced by silicon, but their composition is expressed by the same general formula, $(Fe,Mn)_3(C,Si)$, as is that of ordinary 'ferro-manganese.' In the hope of elucidating the differences in crystalline form and chemical composition presented by this group of substances, other samples of material have been sent by Mr. Stead for crystallographic examination, but unfortunately none of the crystals on these show any definite terminal faces. Besides the material supplied by Mr. Stead, two other specimens, from French iron-furnaces and previously in the British Museum, were examined. I have to express my thanks to Mr. Stead for kindly supplying most of the material for examination, and also for his permission to publish separately the crystallographic results.

The physical characters are much the same in all the seven samples examined. The crystals are of a steel-grey colour, but are often tarnished bronze-yellow; unless covered with a dull, black crust, they have a brilliant metallic lustre. They are very brittle, and have a hardness on Mohs' scale of $6\frac{1}{2}$. They are non-magnetic.

The crystallographic characters of each sample, as far as could be determined, are separately described below under Nos. I to VII. For various reasons, such as the dullness, striation, or repetition of the faces, or the divergent grouping of the crystals, accurate measurements could be obtained only exceptionally. Nevertheless, by measurement of the crystals the different samples could be divided into two sharply defined groups:

(*a*) Crystals showing a rhombic prism-zone with a prism-angle of about $67\frac{1}{2}°$ ($mm''' = 67\frac{1}{2}°$, $bm = 56\frac{1}{4}°$). Terminated crystals (on sample No. I) belong to the orthorhombic system.

(*b*) Crystals showing a pseudo-hexagonal prism-zone with angles varying between 59° and 61°. Terminated crystals (on sample No. IV) belong to the anorthic system.

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Carbo-silicide of Manganese and Iron.

I. This material, from the hearth of a blast-furnace at Blaina, Monmouthshire, has already been described in detail by Mr. Stead[1], and the original mass of crystals described and figured has been generously presented by him to the British Museum. Since then, Mr. E. Poulaine, the general manager of the Blaina Works, has presented to the Museum a finer specimen with much larger crystals, these reaching up to 4½ cm. in length and 1 cm. in thickness. This larger specimen, however, shows nothing essentially different from the specimen already described, and I simply quote my crystallographic results from Mr. Stead's paper.

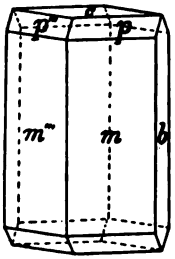

Fig. 1.—Carbo-silicide of manganese and iron.

Crystal class: holohedral-orthorhombic.

Forms: $m\{110\}$, $p\{111\}$, $c\{001\}$, $b\{010\}$.

The faces of the crystals (fig. 1) are dull and drusy, and do not give any reflected image of the goniometer-signal. The mean of several readings taken in the position of maximum illumination gave the following approximate values for the angles:—

$$cp\,(001 : 111) = 51°,\ mm'''\,(110 : 1\bar{1}0) = 66°.$$

The corresponding axial ratios are:—

$$a : b : c = 0{\cdot}65 : 1 : 0{\cdot}67.$$

Carbide of Iron and Manganese ('Spiegeleisen').

II. More exact measurements in the prism-zone were obtained with crystals from a French iron-furnace. The specimen consists of a friable, cellular aggregate of blade-shaped and acicular crystals, which reach up to 10 cm. in length. The crystals, when not broken, have ragged terminations consisting of fine points, and no definite terminal faces could be found.

Measurement of four crystals, both blades and needles, showed that there is a rhombic prism-zone with the forms $m\{110\}$ and $b\{010\}$. The best crystal, from four of the faces of which single, sharp images were reflected, gave

$$mm'''\,(110 : 1\bar{1}0) = 67°\,32'\ \text{and}\ mb\,(110 : 010) = 56°\,14'.$$

[1] J. E. Stead, Crystals of carbo-silicide of manganese and iron. Journ. Iron and Steel Institute, 1901, No. 1, vol. lix, pp. 79–88. Here fig. 2 incorrectly represents the crystals as orthorhombic with inclined hemihedrism.

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The crystals are deeply striated parallel to the length of the prism, and are often quite thin and blade-shaped parallel to the brachypinacoid, $b\{010\}$.

III. This sample shows smaller crystals of the same character as No. II thickly lining the walls of a cavity in compact material. No really good measurements were obtained; the means of all readings from five crystals are:—

$mm''' = 67° 33'$ (limits, $66\frac{1}{2}° - 68\frac{1}{4}°$).
$mb = 56° 12'$ („ $55\frac{1}{2}° - 56° 49'$).

The order in which these angles were repeated on one crystal suggested that it was twinned on a prism-plane.

From the above measurements (Nos. II and III) crystals of 'Spiegeleisen' may belong to either the orthorhombic or the oblique system; the agreement in the prism-angle with that of the carbo-silicide (No. I) makes it very probable, however, that the system is orthorhombic, and that the carbide and carbo-silicide are isomorphous.

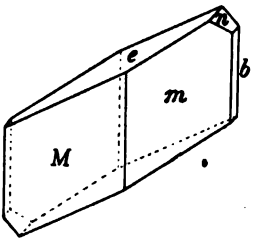

FIG. 2.

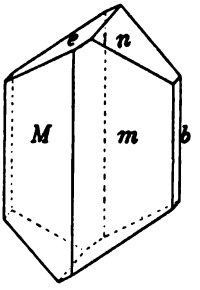

FIG. 3.

Silicide of iron and manganese.

SILICIDE OF IRON AND MANGANESE ('SILICO-FERRO-MANGANESE').

IV. The small and somewhat indistinct crystals line cavities in the crystalline material. The faces of the crystals are rather uneven and have the character of ground glass, but they sometimes give definite reflections; the measurements are therefore only approximate.

Crystal class: holohedral-anorthic.

Elements: $a : b : c = 0{\cdot}58 : 1 : 0{\cdot}66$; $\alpha = 85° 12'$, $\beta = 97° 48'$, $\gamma = 90° 39'$.

Forms: $m\{110\}$, $M\{1\bar{1}0\}$, $b\{010\}$, $n\{011\}$, $e\{0\bar{1}1\}$.

The usual habit of the crystals is illustrated in fig. 2; often n and b

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are quite small or absent, and the crystals then closely resemble acute rhombohedra. On one crystal the faces *n* and those in the prism-zone are more largely developed, as shown in fig. 3. Figs. 2 and 3 represent the actual crystals, each about 1 mm. across, which were measured on the goniometer.

	Measured.	Mean.	Calculated.
bm, 010 : 110	58°–61½°	60° about	—
mM, 110 : 1$\bar{1}$0		,,	—
Mb', 1$\bar{1}$0 : 0$\bar{1}$0		,,	60° 0′
bn, 010 : 011	60° 16′, 60°	60° 8′	60 0
ne, 011 : 0$\bar{1}$1	66 42, 66 37′	66 39	—
eb', 0$\bar{1}$1 : 0$\bar{1}$0	53 13, 53½	53 21	—
nm, 011 : 110	69 29, 69	69 15	69 28
nM', 011 : $\bar{1}$10	81 19, 81½	81 25	—
eM, 0$\bar{1}$1 : 1$\bar{1}$0	66 8, 66 40, 67¼°	66 41	66 56
em', 0$\bar{1}$1 : $\bar{1}$10	78 8, 77, 78	77 43	78 10

Carbide of Manganese and Iron ('Ferro-manganese').

V. This sample is almost pure carbide of manganese with very little iron. It is a compact aggregate of acicular crystals arranged approximately parallel to each other; in small interspaces, bright crystal-faces are developed. The six faces in the prism-zone are of about equal size, and are striated parallel to their mutual intersections. Six crystals were measured, and two or three very good readings obtained, the best being 59° 46′ and 60° 16′ (on the same crystal), while others varied between 59° 22′ and 59° 50′, and between 60° 15′ and 60° 29′. None of the crystals had good faces all round the zone, and no symmetrical or definite repetition of the angles could be detected; it is therefore probable that the crystals are twinned on a prism-plane, as is frequently the case with pseudo-hexagonal crystals.

VI. A friable, cellular network of acicular crystals confusedly arranged. Measurements in the prism-zone varied between 59° and 61°. On one crystal was noticed a rough terminal plane at about 90° to the prism.

VII. A confused aggregate of small needles, much intergrown, in a cavity of compact material. The best angles obtained from five crystals were 59° 34′ and 60° 23′; but again no definite order in the occurrence of the angles around the zone could be traced.

The measurements from samples Nos. V–VII, like those of Mallard and

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Brauns, are insufficient to decide whether the crystals of 'ferro-manganese' belong to the orthorhombic, oblique, or anorthic system; but the occurrence of a similar pseudo-hexagonal zone on the anorthic crystals of 'silico-ferro-manganese' (No. IV) suggests that 'ferro-manganese' may also be anorthic, and that the two are isomorphous. It is to be noted, however, that neither the silicide nor the carbo-silicide follow Mallard's rule as to the relation between the size of the prism-angle and the amount of manganese present. It is possible that the difference in crystalline form does not depend on the amount of manganese, but that we have here an isodimorphous series. The present observations are thus still insufficient to determine the inter-relations of this group of substances, and more measurements from terminated crystals are required.

The following analyses, made in Mr. Stead's laboratory, give, under the corresponding numbers, the chemical composition of the material examined crystallographically. All agree fairly closely with the general formula $(Fe,Mn)_3(C,Si)$.

	Fe.	Mn.	C.	Si.	Prism-angle.
I.	84·80	56·80	3·90	3·31	66° about
II.	59·35 60·00	32·50 33·40	6·08 5·85	0·37 0·28	67° 32′
III.	48·10	44·05	6·40	1·35	67 33
IV [1].	67·40	20·10	1·63	10·50	60° about
V.	very little	—	—	very little	,,
VI [2].	29·80	61·98	6·83	0·26	,,
VII.	—	80	—	very little	,,

Crystals of 'silico-ferro-manganese,' from furnaces at Nijni-Tagilsk in the Urals, have been measured by Eremyeev [3], who found them to belong to the cubic system with the forms {102} and {100}, but distorted so as to simulate orthorhombic symmetry. These crystals are therefore quite distinct from those described above, but as Eremyeev does not give their chemical composition the two kinds cannot be further compared.

The meteoric mineral cohenite, $(Fe,Ni,Co)_3C$, has been proved by

[1] Of massive material, not of crystals. Also P, 0·17; S, trace.

[2] A small amount of graphite was detected between the crystals.

[3] Verhandl. russ.-kais. mineral. Gesell. St. Petersburg, 1879, ser. 2, vol. xiv, p. 246. A German abstract of this note is given in Zeits. Kryst. Min., 1879, vol. iii, p. 488, under the title: P. von Jeremejew. Krystalle des Ferromangansiliciums.

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Hussak[1] to crystallize in the cubic system. This carbide of iron usually contains 2 or 3 per cent. of nickel and cobalt, but smaller amounts were found by Cohen[2] in the cohenite of terrestrial irons from Greenland. It is therefore probable, as pointed out by Groth[3], that the carbide of iron, Fe_3C, which is a constituent of steel and to which the name cementite has been given, is identical with cohenite.

The carbide (Fe_3C) and silicides (Fe_2Si, Fe_3Si_2, FeSi, and $FeSi_2$) of iron prepared in recent years by Moissan and other chemists, although frequently crystallized, do not appear to have been submitted to crystallographic examination.

[1] Archivos do Museu Nacional do Rio de Janeiro, 1896, vol. ix, pp. 130, 160.

[2] Meddelelser om Grønland, 1897, vol. xv, p. 293; Ann. k. k. naturhist. Hofmuseums, Wien, 1897, vol. xii, p. 58.

[3] Tabellar. Uebersicht der Mineralien, 4th edit., p. 16. Braunschweig, 1898.

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NOTES.

We regret to record the deaths of the following mineralogists:—

Dr. Antonio D'Achiardi (1839–1902), Professor of Mineralogy in the University of Pisa. He was the author of numerous papers and textbooks, including a mineralogy of Tuscany, and only a short time ago was elected an honorary member of this Society.

M. Augustin Alexis Damour (1808–1902), who, after his retirement from the diplomatic service in 1854, devoted himself to the chemical study of minerals.

Dr. Friedrich August Frenzel (1842–1902), who advanced from the position of a working miner to that of Director of the Royal Metallurgical Laboratory at Freiberg (Saxony); his talent was recognized by Breithaupt. He was the author of numerous mineralogical papers written since 1870, his well-known 'Mineralogisches Lexicon für das Königreich Sachsen' having been published in 1874.

Professor Paul Gabriel Hautefeuille (1836–1902), member of the Paris Academy of Sciences and Professor of Mineralogy in the University of Paris. He was successful in the artificial preparation of numerous minerals.

M. Vivant Léon Moissenet (1831–1901), formerly Professor of Assaying in the École des Mines, Paris, and an honorary member of this Society since 1877; he was the author of several papers on the mineral-veins of Cornwall.

Dr. Carlo Riva (1872–1902), Docent in Petrology and assistant in the Mineralogical Laboratory of the University of Pavia; his early death was the result of an accident in the Alps.

The Rev. Dr. Thomas Wiltshire (1826–1902), formerly Professor of Geology and Mineralogy in King's College, London, and a member of this Society. His collection of minerals he gave, a few years ago, to the Mineralogical Museum at Cambridge.

An effort is being made by the mayor and municipal council of St. Just-en-Chaussée, dép. Oise, to raise a memorial to two famous men, the brothers Haüy, who were born at that town: René Just (1743–1822), abbé and mineralogist, was the founder of mineralogy as an exact science; Valentin (1746–1822), philanthropist, was the founder of the

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first school for the blind. The French and English mineralogical societies are interesting themselves in the appeal for subscription, and it is to be hoped that the sum of 25,000 francs required to carry out the project will soon be raised.

To the extensive donations of Mr. J. Pierpont Morgan to public mineral collections, noted in the last number of this Magazine, must now be added that of a collection of precious stones recently presented by him to the Muséum d'Histoire Naturelle at Paris. This collection, consisting of 600 specimens of facetted and rough stones, was brought together by Mr. G. F. Kunz for the Pan-American Exposition of 1901 to illustrate the occurrence of precious stones in both North and South America, and especially in the United States, and is said to be one of the finest and most complete collections of its kind.

Among the several exhibits of mineralogical interest at the Royal Society's Conversazione in May last may be mentioned the microscope preparations of meteoric and artificial irons shown by Mr. J. E. Stead. When polished surfaces are heated in air the various constituents—metallic iron, carbide and phosphide of iron—acquire different oxidization tints, which in reflected light rival in brilliancy the polarization colours of a transparent mineral section. In this way was shown the minute structure of a piece of artificial iron in which small, but beautifully marked, Widmanstätten figures had been developed by the very slow cooling of the mass from a high temperature.

It is interesting to remember that this method of 'heat-tinting' was the way by which the crystalline structure of meteoric iron was shown by Widmanstätten in 1808. The method has, however, been recently developed by metallographers, and, in conjunction with Koenigsberger's method of detecting polarization of light reflected from the surfaces of opaque crystals (abstract, this vol., p. 208), should find an extensive application in the study of meteoric irons.

The rare event of the fall of a meteoric stone was witnessed on September 13, 1902, near Crumlin in co. Antrim. The weight of the stone is 9 lb. 5½ oz., and it measures $7\frac{1}{2} \times 6\frac{1}{2} \times 3\frac{1}{2}$ inches; it is thus the largest stone which has been observed to fall in the British Isles for eighty-nine years. The stone was acquired for the British Museum collection through Mr. Fletcher, who has given a preliminary account of the fall and of the stone itself in 'Nature' (vol. lxvi, p. 577).

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In addition to the Crumlin meteorite, mentioned above, the following noteworthy recent additions to the mineral collection of the British Museum may be mentioned:—

A large crystal of topaz, measuring two feet in length and weighing 137 pounds, from Sætersdalen, Norway.

A large and valuable collection of native gold and gold tellurides from Western Australia, presented by the Government of Western Australia and by various gold-mining companies. A description of these specimens is given above on p. 268, and a selection of them is exhibited in the recent acquisition case in the Mineral Gallery.

We have received several descriptive catalogues and guides reprinted from the Report of the United States National Museum at Washington. One of these, by Mr. George P. Merrill, on the non-metallic minerals exhibited in the section of Applied Geology, extends to 330 pages and is illustrated by 30 excellent plates together with several text-figures, and is in itself a valuable text-book on the economic applications of minerals. Other catalogues, by Mr. Wirt Tassin, deal with the collection of precious stones (200 pp., 9 plates and 26 text-figures), the collection of meteorites, and a collection illustrating the properties of minerals, while another outlines the classification adopted for the systematic collection of minerals.

From the annual report for 1899–1900 we learn that the same museum has acquired the private collection of minerals of the late Professor C. U. Shepard; this includes some 5,000 selected specimens, many of them types described by Professor Shepard and of great rarity.

A small handbook, 'Aids to the Analysis and Assay of Ores, Metals, Fuels, &c.,' by J. James Morgan (London, 1902, viii + 105 pp. Price 2*s.* 6*d.*, or in paper covers 2*s.*), has been received from the publishers, Baillière, Tindall & Cox. It gives concise instructions for the execution of various technical analyses.

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ABSTRACTS.

On the Use of the Stereographic Projection for Geographical Maps and Sailing Charts (S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiii, pp. 245–75, 347–76).

On the Solution of Problems in Crystallography by means of Graphical Methods, based upon Spherical and Plane Trigonometry (S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 249–84).

These papers arise from and are particular developments of an earlier paper by the author, 'The Stereographic Projection and its Possibilities, from a Graphical Standpoint' (Amer. Journ. Sci., 1901, ser. 4, vol. xi, pp. 1–24, 115–44.—Abstract, this vol., p. 203). Both open with a brief explanation of this projection and of the employment of the protractors devised by the author.

In the first paper the author proceeds to explain clearly how a map should be constructed on these principles, and how from it the distances between any two points shown thereon may be accurately determined. The important question of distortion is discussed, and shown to be very small up to about 70° from the centre, and not very great even up to 90°. The large stereographic map of the United States, a reduced copy of which is shown, is treated in detail. Examples of measurements between various towns by means of a scale of miles are given and compared with the values obtained from calculation or measured on a polyconic map. Even without applying some easy corrections the measurements on the stereographic map are wonderfully accurate and greatly superior to those made on a polyconic map. In the application to navigation the superiority of this projection for great-circle sailing is made obvious. The author concludes his paper by protesting against the inaccurate maps and scales obtaining in almost all school atlases and geographies.

In the second paper the author employs the projection for the graphical determination from observation of the fundamental constants and indices of the faces. Examples of crystals belonging to each of the six systems are worked out in detail. The author in conclusion lays stress on the advantages of these methods both as a check on the accuracy of computation and as a means of grasping the principles underlying the mathematical formulae. G. F. H. S.

Simpler Methods in Crystallography (J. G. Goodchild, Proc. Roy. Phys. Soc. Edinburgh, 1901, vol. xiv, pp. 323–59; 1902, vol. xiv, pp. 403–34).—The author describes methods for the construction of

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projections from the fundamental constants and indices of the faces. The methods do not depend on the angles between faces and involve no knowledge of plane or spherical trigonometry. The author discusses the gnomonic and stereographic projections for the different systems, treating the case of anorthic crystals at some length. He proceeds to show how the indices of faces may be determined from the observed zonal relations with the help of a stereogram. He adds a method for drawing crystals in the clinographic position, and gives a practical rule for obtaining the axial cross required, showing how it must be modified for systems other than the cubic. G. F. H. S.

Crystalline form of Geikielite (P. von Sustschinsky, Zeits. Kryst. Min., 1902, vol. xxxvii, pp. 57–62).—An examination of new material, brought from Rakwana, Ceylon, by Dr. Grünling (abstract, this vol., p. 93), has led to the determination of the crystalline form of geikielite, a point which was left undecided in the original description of this mineral (this Magazine, vol. x, p. 145). The material cleaves parallel to the faces of a rhombohedron of 94°7′; one cleavage is good, another poor, while the third was only obtained after several trials. [This would indicate planes of parting rather than true cleavage.] The basal plane is represented by crystal-faces and by planes of parting. On one small and rather indistinct crystal were faces belonging to the forms $c\{111\}$, ϕ $\{611\}$, and perhaps $\{\bar{1}11\}$, but no cleavage was observed. The measured value of the cleavage angle, rr' $(100:010) = 94°7'$, corresponds to the axial ratio $a:c = 1:1{\cdot}370$.

Analyses agree with the formula $MgTiO_3$, but show a small excess of ferric oxide. The sp. gr. of the material is 3·976. The small rounded masses of geikielite are sometimes embedded in laterite, which also contains small grains of quartz and grains and octahedra of colourless spinel. Rutile is intergrown with the geikielite. L. J. S.

Chemical Composition of Xenotime (E. H. Kraus and J. Reitinger, Zeits. Kryst. Min., 1901, vol. xxxiv, pp. 268–77).—The xenotime of Dattas near Diamantina in Brazil, analysed by Gorceix in 1886, is shown by a new analysis (I) not to be an orthophosphate, but a sulphato-phosphate of the rare earths with the formula $3R_2O_3{\cdot}3P_2O_5{\cdot}SO_3$: the new name, *hussakite*, is given to it because of this difference in chemical composition. The mineral occurs, in a perfectly fresh condition, in sands as long prismatic crystals which are transparent and of a yellow to brown colour: the cleavage, interfacial angles, and other characters are the same as for ordinary xenotime; sp. gr. 4·507.

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	SO_3	P_2O_5	Y_2O_3	Er_2O_3	Gd_2O_3	Fe_2O_3	Al_2O_3	CaO	MgO	Total.
I.	6·18	33·51	43·43	14·82	1·99	0·20	traces			100·06
II.	2·68	27·37	45·86	13·67	0·42	4·54	1·16	2·56	0·45	99·70

Analysis II (contains also: SiO_2, 0·62; H_2O, 0·37 per cent.) is of pyramidal crystals of cloudy, opaque xenotime from sands at Bandeira de Mello, Bahia, Brazil. This appears to be intermediate between xenotime and hussakite. Sulphuric anhydride was also detected in slightly altered xenotime from Hitterö, but not in the much altered xenotime of other Norwegian localities. It thus appears that hussakite is liable to alteration, the sulphuric anhydride being extracted, and that ordinary xenotime is really a pseudomorph after hussakite. This is supported by the fact that sulphuric anhydride is easily extracted from powdered hussakite by digestion with soda solution.

[The authors have made the important observation that the chemical composition of xenotime has been previously incorrectly determined, but they do not appear, on this account, to be justified in giving a new name, which, if done in other similar cases, would lead to an unnecessary multiplication of mineral names.] L. J. S.

A new Cadmium Mineral (E. Wittich and B. Neumann, Centralblatt Min., 1901, pp. 549–51; and Chemiker-Zeitung, 1901, vol. xxv, pp. 561–2).—The new mineral, cadmium oxide, CdO, was found as a black shining incrustation, and as powder, on a mass of ferruginous zinc silicate from Monte Poni, Sardinia. The minute crystals are regular octahedra, sometimes with cube planes, and resemble the artificial crystals obtained when cadmium is burnt in oxygen.

Although small quantities of cadmium are of fairly wide distribution in zinc minerals, yet the only cadmium mineral previously known is greenockite (CdS). L. J. S.

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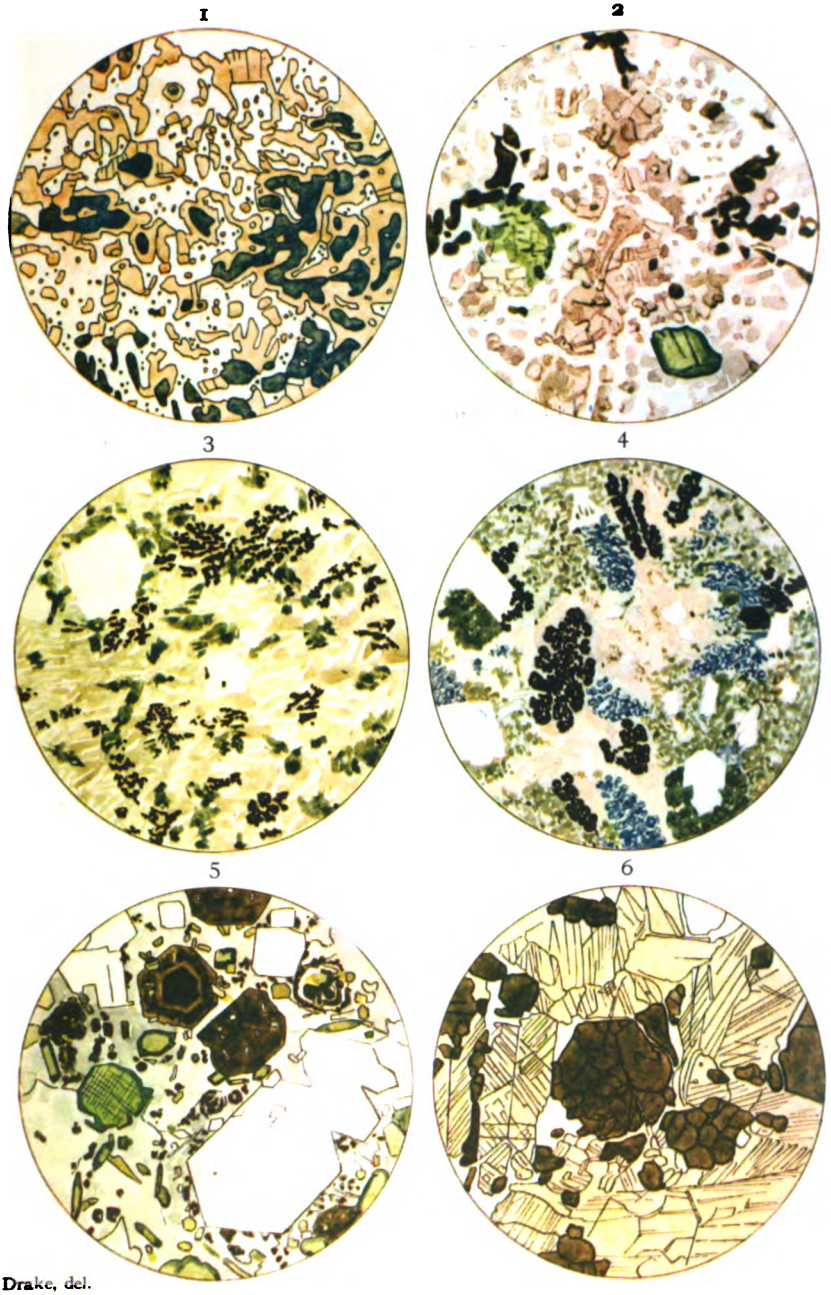

E. Drake, del.

G. T. PRIOR: ROCKS FROM BRITISH EAST AFRICA.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF

THE MINERALOGICAL SOCIETY.

No. 62. DECEMBER, 1903. Vol. XIII.

On the advantages of the Gnomonic Projection and its use in the Drawing of Crystals.

(*With a table to facilitate its employment.*)

By G. F. Herbert Smith, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read June 10, 1902.]

Of the various methods employed or suggested for the graphical representation on a plane of points on the surface of a sphere, the most important to the crystallographer are the stereographic and the gnomonic projections. Both are in common use, and both have their particular advantages. Professor Penfield has recently published a series of papers[1] in which he points out the advantages that accrue from the employment of the stereographic projection both in crystallography and cartography. He has devised protractors and scales, which facilitate the construction of the projection of the poles of the faces bounding a crystal or of portions of the earth's surface, and enable the angles between points or contained by zones, i. e. great circles, to be readily determined from measurements on the plane diagram. This projection is especially advan-

[1] 'The stereographic projection and its possibilities from a graphical standpoint.' Amer. Journ. Sci., 1901, ser. 4, vol. xi, pp. 1–24, 115–144; abstract, this vol., p. 203. 'On the use of the stereographic projection for geographical maps and sailing charts.' Amer. Journ. Sci., 1902, ser. 4, vol. xiii, pp. 245–275, 347–376; abstract, this vol., p. 306. 'On the solution of problems in crystallography by means of graphical methods, based upon spherical and plane trigonometry.' Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 249–284; abstract, this vol., p. 306.

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tageous for use in the construction of maps, because the meridians and parallels are projected as arcs of circles, and are, therefore, easily drawn. We must not, however, overlook the very considerable merits of the gnomonic projection in crystallographical work, especially in the investigation of complicated zonal relations. The author found it of inestimable service in the study of the crystalline development of calaverite[1], but the ordinary method of plotting, such as is described in the textbooks, is awkward, and a projection is not easy of construction. The purpose of this paper is to show that, by means of the table given at the end, the spherical coordinates of any pole may readily be converted into plane coordinates, and, by means of a particular form of protractor, these poles may be plotted on a plane diagram. Further, it will be seen that, with the aid of the table and protractor, the angles between points or contained by zones may be graphically determined on the plane diagram just as in the case of the stereographic projection.

The gnomonic[2] is a perspective projection in which the point of vision is at the centre of the sphere and the poles are projected on to a plane touching it. The point of contact with the sphere, which is the point where the perpendicular from the centre meets the plane, is called the centre of projection. Since the planes of all great circles pass through the centre of the sphere, zones are represented in the projection by straight lines of infinite length. In this property lies the principal advantage of the method; for the zonal relations subsisting between the faces of a crystal are easily tested by means of a straight-edge. This is obviously a simpler criterion than that in the stereographic projection in which three tautozonal poles must lie on the same circular arc, the common chord of which and the primitive circle must be a diameter of the latter. All poles on the great circle whose plane is parallel to the plane of projection are projected to infinity, and hence only a portion of the sphere can be represented on the same diagram. These poles are distant a right angle from the centre of projection, and therefore the angle between any pair is the same as the angle between the zones connecting them with the centre of projection. We can thus represent them by the corresponding zones. This is effected in practice by ter-

[1] This vol., pp. 122–150. A translation appeared in Zeits. Kryst. Min., 1903, vol. xxxvii, pp. 209–234.

[2] For other discussions of this projection see:—'Crystallography; a Treatise on the Morphology of Crystals,' by N. Story-Maskelyne, Oxford, 1895, pp. 492–499. H. A. Miers, 'The gnomonic projection,' Min. Mag., 1887, vol. vii, pp. 145–149. 'Traité de Cristallographie,' by E. Mallard, Paris, 1879, vol. i, pp. 63–66. 'Projection und graphische Krystallberechnung,' by V. Goldschmidt, Berlin, 1887.

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minating the diagram by some arbitrary boundary—perhaps the best, a circle—and marking on a similar one outside it the intersections with the lines representing the zones. A projection will not be of inconvenient size which includes all poles lying within an angular distance of about 65° from the centre of projection. Thus on a single diagram we can represent nearly all the faces forming one termination of the crystal and also the faces in the zone of reference. Since the linear distances from the centre of projection are tangents of the corresponding angle, the resulting diagram suffers considerably from distortion, and cannot

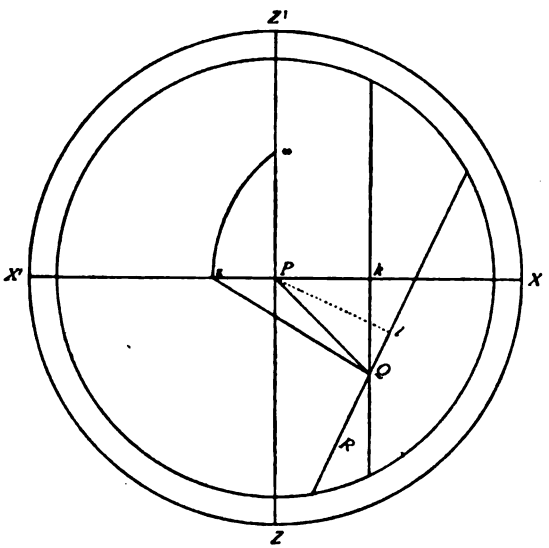

FIG. 1.—Gnomonic projection.

conveniently be used for mapping portions of a sphere. Another disadvantage practically prohibits its employment for this purpose, viz. that parallels of latitude are projected as conic sections, and are only circles in the particular cases when either the north or the south pole is the centre of projection.

Anything like general use of the gnomonic projection has probably been hindered by the difficulty of constructing a diagram from the observations made on a crystal. No difficulty, however, arises if we make use of the methods devised for the measurements of crystals by means of a three-circle goniometer. Measurements are made from poles in a certain zone, known as the zone of reference, as origins, and from

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the readings of the circles we obtain for any pole its distance from the origin and its azimuth from the zone of reference. In order to assure the observation of all the faces on the crystal, we should make a systematic survey from one particular origin (including with it the one diametrically opposite). The coordinates thus determined are used for locating the poles of the faces on the diagram, whose plane is taken at right angles to the edge of the zone of reference. All poles in this zone are projected to infinity on the diagram, and consequently all zones passing through the same origin appear as parallel lines.

We may now consider what are the corresponding linear coordinates of a point in the diagram. In fig. 1, P, the pole of the zone of reference, is the centre of projection, and Z the origin on the zone of reference; PX is drawn at right angles to PZ; Q is any point, and Qk is drawn parallel to PZ, and consequently at right angles to PX. Qk is therefore the zone passing through Q and the origin, Z.

If the spherical coordinates of the pole, represented by Q, with respect to the origin, Z, be

ρ, the distance from Z,
ϕ, the azimuth from the zone of reference,

the corresponding linear coordinates are easily seen to be

$$kQ = r \cot \rho \operatorname{cosec} \phi,$$
$$Pk = r \cot \phi,$$

where r is the radius of the sphere of projection.

One coordinate, Pk, representing the azimuth, is readily found from a table of tangents; but as yet either the other must be calculated or the position of Q be found graphically. In the latter method[1] we have successively to find a point ω (fig. 1) in PZ such that $P\omega = r$, the radius of the sphere of projection, and a point κ in PX such that $k\kappa = k\omega$; then the plane angle $Q\kappa k$ is the complement of ρ. Such a method, entailing as it does the use of subsidiary points and lines and of several operations, each liable to error, is exceedingly troublesome to carry out in practice, and may result in considerable confusion and inaccuracy, as, indeed, the author is aware from experience.

At the end of this paper is given a table containing the values of cot ρ cosec ϕ (multiplied by 10 for convenience) for every degree from 90° to 25°. In the columns the azimuths are constant, and in the rows the distances. Since cosec 90° is unity, the first column gives the

[1] Cf. Story-Maskelyne and Miers, loc. cit.

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cotangents (multiplied by 10) for every degree, and we may therefore use this column to find the coordinate *Pk*, corresponding to the azimuth.

The use of the table will be made clear from an example. Suppose we wish to locate a pole whose azimuth and distance are respectively 60° 40′ and 55° 10′. Under the column headed 60° we find the value corresponding to 55°; we proceed to subtract the proportionate difference in the column for 10′ and in the row for 40′. Thus we actually obtain 8·09 less 0·05, 8·04, and finally, less 0·05, 7·99. The two plane coordinates are therefore 5·62 and 7·99, multiplied or divided by a constant depending on the length assigned to the radius of the sphere. In

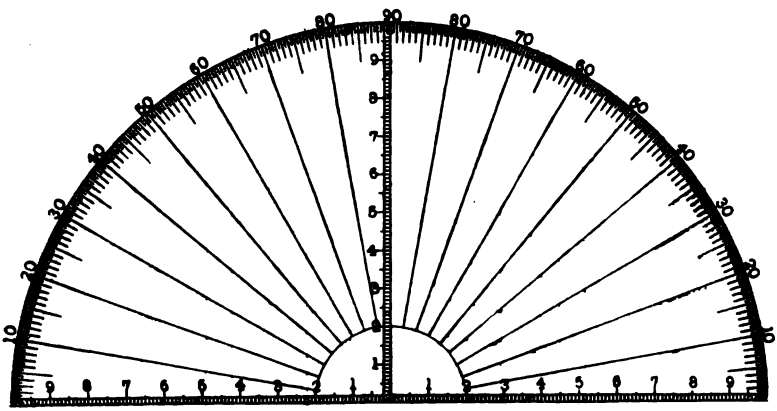

FIG. 2.—Protractor for plotting gnomonic projections.
(Half actual size.)

practice we find the coordinate corresponding to the azimuth first, because there will usually be several poles with the same azimuth. We notice that the plane coordinates increase as the spherical coordinates diminish, and vice versa. All subsidiary work required in the determination of these coordinates may be done on a separate sheet of paper, and the diagram need have no subsidiary lines or points on it at all.

Squared paper, for instance, divided to millimetres, is convenient for plotting the positions of poles, but ordinary blank paper may be used in conjunction with the form of protractor shown in fig. 2. This consists of a strip of celluloid on which is engraved a semicircle. The diameter, which is on the edge of the strip, and the radius at right angles to it are graduated to millimetres. By means of these two scales, mutually at

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right angles, we can easily plot the poles from their plane coordinates. To avoid parallax, the engraved side of the celluloid strip should be placed next to the paper. If a pencil be used for plotting, allowance must be made for its thickness. It is perhaps best to use a pin or a needle, which will accurately mark a point just under the edge of the strip. A line must be drawn on the sheet of paper corresponding to PX (fig. 1), and a point marked on it to represent P. Then the protractor is moved about so that the shorter scale lies on this line. The purpose of the graduated semicircle is explained below (p. 316).

In applying the above method to measurements on a goniometer with a single circle, it will be necessary to calculate at least one angle. The majority of the poles may, however, then be located from their positions

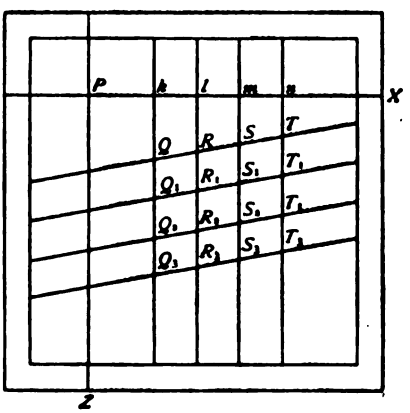

FIG. 3.—Gnomonic projection.

in known zones. In the case of measurements on a goniometer with two circles it may be more convenient to take the centre of projection as origin. In that case the azimuths are the same as the plane angles between the lines on the diagram corresponding to the zones, and the linear distances, e. g. PQ in fig. 1, are proportional to the tangents of the corresponding angle.

We may now proceed to consider a remarkable property of this projection. In fig. 3 we have a series of poles lying in zones passing through the same origin in the zone of reference. Let their azimuths be ϕ, ϕ_1, ϕ_2, ϕ_3. From what has preceded we see that

$$\frac{km \,.\, ln}{kl \,.\, mn} = \frac{(\cot\phi_2 - \cot\phi)(\cot\phi_3 - \cot\phi_1)}{(\cot\phi_1 - \cot\phi)(\cot\phi_3 - \cot\phi_2)} = \frac{\sin(\phi - \phi_2)\sin(\phi_3 - \phi_1)}{\sin(\phi - \phi_1)\sin(\phi_3 - \phi_2)} =$$

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a rational quantity, being the anharmonic ratio of a pencil of four crystallographically possible zones, intersecting in the same pole.

Suppose now that $\{T T_1 T_2 T_3\}$ is the zone of reference. Then n lies at infinity, and we are left with the very simple relation

$$\frac{km}{kl} = \text{a rational quantity.}$$

The same relation also holds with regard to poles in a zone, and accordingly we have

$$\frac{QQ_2}{QQ_1} = \text{a rational quantity.}$$

The principal zones in the diagram are thus equally spaced apart, and the same is true of zones passing through any other origin on the zone of reference. The diagram may therefore be divided into a network of equal parallelograms[1], or in special cases rectangles or squares. A necessary consequence follows that the unit linear distances on parallel lines must be the same. This is a most important property, for we have merely to take measurements on the diagram to determine the simple indices corresponding to any particular face.

We will now show that the angles between poles or contained by zones may be graphically determined from the projection with the aid of the protractor and the table.

To find the angle between two poles, represented by points on the gnomonic projection.—Let Q and R (fig. 1, p. 311) be the two points, and P the centre of projection. Place the protractor on the diagram so that the diameter lies along QR, and at the same time the radius passes over P. The zero point then lies on l. Take the readings for P, Q, and R. If necessary, multiply or divide these by a constant quantity, depending upon the length selected for the radius of the sphere of projection. The reading for P gives the length Pl, and from the table the azimuth of the zone QR can be found. Knowing this, we can further find from the table the angular distances corresponding to the observed linear lengths Ql and Rl. The sum or the difference must be taken according as Q and R lie on opposite sides or on the same side of Pl. In the latter case we have the angle required, but in the former the supplement, because the table gives the distance measured from the origin in the zone of reference.

[1] It may be noted that in the triclinic system P will not be a node of the network.

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To find the angle between any two zones, represented by straight lines on the gnomonic projection.—Let the zones intersect in D and meet the zone of reference in p_1 and p_2 (fig. 4 *a*). To make the reasoning clearer the corresponding stereographic (fig. 4 *b*) is placed alongside the gnomonic projection. Draw the zone PD and let it meet the zone of reference in d.

Let the angle Dd be ϕ, the angles p_1d and p_2d be the complements of ρ_1 and ρ_2, and the angles p_1Dd and p_2Dd be D_1 and D_2 respectively. Then we have in the triangles p_1Dd and p_2Dd

$$\tan D_1 = \cot \rho_1 \operatorname{cosec} \phi,$$
$$\tan D_2 = \cot \rho_2 \operatorname{cosec} \phi.$$

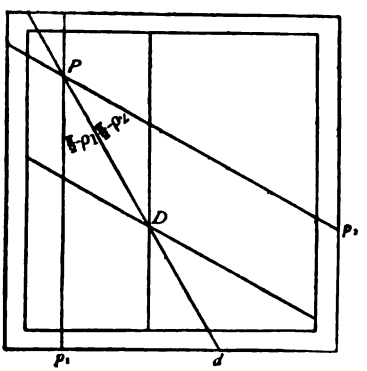

FIG. 4 *a*.—Gnomonic projection.

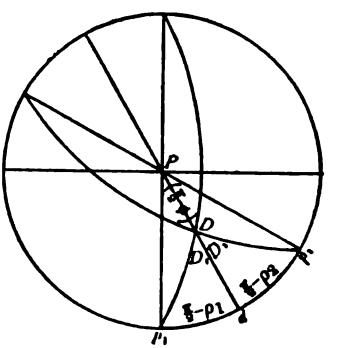

FIG. 4 *b*.—Stereographic projection.

If we now place the protractor on the diagram, so that the zero point is on D and the radius, the reading of which is 90°, passes over the centre of projection, and note the readings of P on the radius scale and those of the two zone-lines on the circular scale, from the first we obtain the length PD, and therefore in the same way as before from the table the angle ϕ, and from the other two we obtain the angles ρ_1 and ρ_2, because the circle is so graduated that the radius, from which we are really measuring, reads 90°. Now the formula given above is the same as that found for the determination of the plane coordinate corresponding to the distance of a pole. We may therefore proceed in the same way. Treating ϕ as an azimuth and ρ as a distance, we get from the table a corresponding quantity, which from the first column we convert into the complement of D_1 or D_2, because this column gives the cotangents. The sum or difference must be taken according as the angles have been

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measured on opposite sides or on the same side of PD. As before, we have in the latter case the angle required, but in the former its supplement.

The Representation of Crystals.

Another important property of the gnomonic projection is the facility it affords for drawing crystals in any position. It is customary to suppose the eye sufficiently distant from the crystal for the imaginary lines connecting it to different parts of the crystal to be sensibly parallel. Thus all edges which are parallel on the crystal, i. e. which form the intersections of pairs of faces lying in the same zone, are parallel in the drawing, and the zonal relations are apparent from inspection. Now the edges common to pairs of faces in a zone are parallel to its axis, and in the gnomonic projection zone-planes are represented by straight lines. If we project this axis orthogonally on to the same plane of projection, the line passes through the centre of projection and is at right angles to the zone-line. Hence to prepare an orthographic drawing of a crystal on any plane, we have only to project the poles gnomonically on to the same plane, and the edge common to a pair of faces is given by a line at right angles to the zone-line in which their poles lie.

If the projection be made, as suggested earlier in this paper, so that the edge of some zone is perpendicular to the plane of the paper, the resulting drawing gives a correct idea of the distribution of the faces on the portion of the crystal in view, but the appearance is very flat, because the edges common to pairs of faces in the zone mentioned are represented only by points, and there is a consequent want of solidity. To gain this effect, we must suppose the crystal to be slightly rotated about the vertical and horizontal axes successively in the plane of the paper. The faces, which had previously been at right angles to the plane of the paper, now come into view, and the drawing of the crystal presents the solid appearance desired.

We will now consider how we may determine the positions of the poles after rotation. Suppose we have three rectangular directions fixed in space, OX, OY, OZ (fig. 1), of which OY is perpendicular to the plane of the paper and represented by P, the centre of projection. The crystal is rotated about OZ and OX successively. To take a concrete instance, let us suppose these rotations are 20° and 10° respectively, and consider the effect on a pole whose azimuth and distance from Z are 38° 35′ and 49° 26′ respectively, the rotation increasing the

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azimuth in each case. After the first rotation these become 58° 35′ and 49° 26′, the latter of course being unaltered. We now have to find the new spherical coordinates with respect to X. From the table we find that the plane coordinates with respect to Z are 6·11 and 10·03; with respect to X therefore they are 10·03 and 6·11, or in spherical coordinates 44° 55′ and 66° 38′. After rotation of 10° about OX we have the coordinates, 54° 55′ and 66° 38′, and obtain from the table the corresponding plane coordinates, 7·03 and 5·28. Reversing these, we find that the coordinates which were 12·54 and 13·78, corresponding to 38° 35′ and 49° 26′, are now 5·28 and 7·03. These must be multiplied or divided by a constant depending on the length assigned to the radius of the sphere. Since for the purpose of delineation extreme accuracy in the position of the poles is not essential and the projection should be as compact as possible, 2 cm. will be a convenient length to give to this radius, and the coordinates after rotation are therefore 1·06 and 1·41 cm. parallel to PX and PZ respectively. In practice we should make the transformations on a separate sheet of paper in the following way :—

			Azimuth	Distance	
Before rotation	plane coordinates		12·54	13·78	Measured from Z
	spherical ,,		38° 35′	49° 26′	
	,, ,,		58° 35′	,, ,,	
After first rotation (20° about OZ)	plane ,,		6·11	10·03	
	spherical ,,		44° 55′	66° 38′	Measured from X
After second rotation (10° about OX)	,, ,,		54° 55′	,, ,,	
	plane ,,		7·03	5·28	
	,, ,,	($r=2$ cm.)	1·41 cm.	1·06 cm.	

After plotting a few poles we may determine the positions of the remainder with sufficient accuracy as the intersections of zones. Four poles, no three of which are tautozonal, are theoretically enough; but it is advisable to plot a few more as a check on the accuracy of the work.

This method applies equally well to all systems. In plotting *ab initio*, the edge of some zone is taken perpendicular to the plane of the paper. Where possible, it would naturally be the zone whose edge in the resulting drawing is most foreshortened, so that the rotations which have first to be applied are not large. If this zone is [100,001], the face (010) is represented by P in all systems save the triclinic. When the axes are at right angles, the faces (100) and (001) would naturally be represented by X and Z. In any system we should plot the new posi-

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tions of the faces (010), (110), ($\bar{1}$10), (011), (01$\bar{1}$), (111), ($\bar{1}$11), (11$\bar{1}$), ($\bar{1}$1$\bar{1}$). These would suffice to give accurately the positions of the initial zone-lines, and the remainder may be determined by graphical construction. In the general case, in which these particular poles are not for some reason available, we select in the most convenient way eight poles, which lie by pairs on four zone-lines intersecting in a ninth.

Since the rotations are usually not large, it will not be possible to plot on a sheet of convenient size the poles representing faces in the zone, whose edge was originally perpendicular to the plane of the paper, unless the radius of the sphere is taken too small. For instance, if we employ the rotations suggested by Haidinger, namely, 18° 26′ and 7° 11′, the distances of (001) and (100) from the centre of projection after rotation, assuming that these poles originally coincided with Z and Y, are 7·9 r and 3·0 r, where r is the radius of the sphere. We can, however, easily obtain the direction of the edge common to the faces lying in this zone in another way. P is its pole in the altered position. If P' be the new position of P, PP' will be the orthogonal projection of the axis of the zone, and therefore gives the direction of the edge in question. Other zone-lines passing through poles on this zone may be determined by means of poles on them, which are located in accessible portions of the diagram.

We can further determine from the gnomonic projection the proper length on the drawing for any edge. It is the actual length on the crystal multiplied by the sine of the angle it makes with the normal to the plane of the paper. This angle is the same as the azimuth of the zone, whose axis is parallel to the particular edge, as given earlier in this paper (p. 312). Hence if we know the actual length of any edge we can readily find its projected length. This is a very useful check on the accuracy of the work.

In this method twin crystals present no greater difficulties than simple crystals. The poles of corresponding faces on the two individuals lie on a line passing through the pole of the twin-axis and make equal angles with it. We have shown above how to find the angle between the faces represented by two points. After plotting a few poles in this way, the remainder may as before be determined from the intersections of zones.

The method here described is precisely the same as that of Mohs and Haidinger[1] as regards the resulting drawing; but these authors obtain

[1] Haidinger, 'Account of the method of drawing crystals in true perspective, followed in the Treatise on Mineralogy of Professor Mohs.' Mem. Wernerian Soc. Edinburgh, 1824–5, vol. v, pp. 485–508.

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the directions of the edges in another way. The projections of the thr fundamental axes and the unit intercepts made on them have first to determined. This is a troublesome process *ab initio*. In practice crystallograph is used, an instrument consisting of three coplanar arr inclined to one another at the proper angles and graduated according the several projected unit lengths. For the cubic system we have once the fundamental factors required; for any other system we mu introduce modifications, maybe only in the units, but in the case of t monoclinic and triclinic systems in both units and angles. The d termination of the fundamental factors for the second individual a twin presents considerable difficulties. When we have at leng drawn the axes and marked off the unit lengths on each, we find t position of any face from the relative intercepts it makes on the axe If we suppose two faces meet one axis in the same point, the direction the common edge is given by the line connecting this point to the inte section of the two lines, belonging to each face, which join the point where they meet the other axes. In practice many difficulties and possi bilities of error arise. If the crystal is at all complicated, confusion may occur from multiplicity of lines that must be drawn for the deter- mination of the various edges. We have further to remember, that an intercept is derived directly not from the corresponding index, but from its inverse; and we must be careful of the signs. None of these difficulties are encountered if the gnomonic projection be employed to give the directions of the edges. Then, again, in this method we may select the rotations most suitable for displaying the symmetry of the faces and their disposition on a crystal. If a crystallograph be used, we are confined to particular angles, usually those suggested by Haidinger, namely, $\tan^{-1}\frac{1}{3}$ (18° 26′) and $\sin^{-1}\frac{1}{6}$ (7° 11′).

Another method frequently employed is that of Naumann[1], which only differs from the preceding in that the paper is supposed to move with the crystal in the second rotation, or, as Naumann expresses it, the eye moves up[2]. The paper is now inclined to the line of sight and the projection is clinographic. Its principal recommendation is the simple practical rule[3] whereby the projections of the axes and the unit intercepts on each may be determined; otherwise it has no superior merits, and the after-procedure is precisely the same as in the orthographic method.

To illustrate the method described above, a combination of the cube,

[1] 'Lehrbuch der reinen und angewandten Krystallographie,' Leipzig, 1830, vol. ii, pp. 400–488. [2] Loc. cit., p. 401. [3] Loc. cit., p. 403.

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octahedron, and dodecahedron is drawn in fig. 5. We first draw the gnomonic projection with the pole of a cube face coincident with the centre of projection. In the actual drawing the radius of the sphere was given a length of 2 cm. We now give the system rotations of 20° and 10° about the vertical and horizontal axes, respectively, in the plane of the paper, as shown in the figure, and obtain another projection.

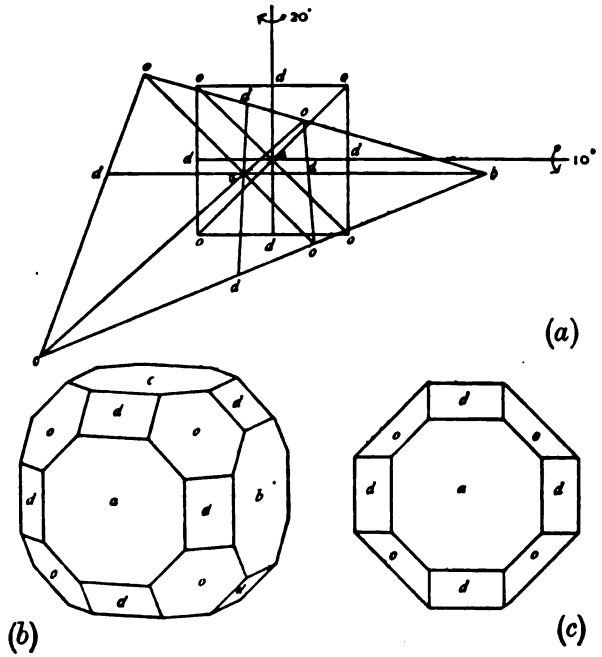

FIG. 5.—Plan (*c*) and orthographic drawing (*b*) derived from the gnomonic projection (*a*) of a crystal.

From these projections we prepare drawings of the crystal in the two positions. The drawings represent crystals of exactly the same size, the lengths of the projections of the various edges having been calculated in the manner described above.

The table appended to this paper gives the values of $10 \cot \rho \operatorname{cosec} \phi$ for every degree from 90° to 25°, where ρ and ϕ represent the distance and azimuth of a pole measured from an origin in the zone, whose edge is at right angles to the plane of the paper, the azimuth being measured from this zone. The purpose of the table is explained above (p. 313).

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Communications from the Oxford Mineralogical Laboratory, No. VI.

1. Note on Mica (Fuchsite) as a decorative stone used by the ancients: by Professor H. A. Miers, F.R.S.

2. Note on the Refractive Indices of Pyromorphite, Mimetite, and Vanadinite: by H. L. Bowman (p. 324).

2. Note on some rare twins of Calcite from Somerset: by H. L. Bowman (p. 329).

4. On some crystals of Quartz from De Aar (Cape Colony) and other localities: by T. V. Barker (p. 331).

Note on Mica (Fuchsite) as a decorative stone used by the ancients.

By Professor H. A. Miers, F.R.S.

[Read March 25, 1902.]

THE specimen to which the following note refers was found in the Oxford Collection, and nothing is known of its origin.

It is a polished piece of translucent emerald-green stone, with patches of darker green and also patches of a dull brown colour.

The stone has taken a high polish, and brilliant internal reflections from immediately below the surface of the paler portions give it in those parts almost the appearance of a flawed emerald. But the fractured surface shows it to be merely a massive, pale green, micaceous mineral with brown patches, which appear at first sight to be only an iron-stained variety of the same substance.

The fragment is a portion of the right leg of a statuette of a nude figure, and of excellent workmanship; it is three inches in length, and extends from the hip to the knee; holes bored into the two ends indicate that the statuette was composed of small segments joined together, and suggest that the material could not be obtained in larger pieces.

I have never seen any decorative or sculptural work in which this material has been used, neither have the archaeologists to whom I have shown it. They unite, however, in attributing the work to a Roman artist and to the best period.

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It is unfortunate that the rest of the statuette has disappeared, for it would have been interesting both on account of its material and its workmanship.

The mineral appears to be a pale green mica, consisting of small plates; cleavage flakes examined under the microscope yield an axial angle of about 70°, and a negative bisectrix not quite perpendicular to the cleavage. The specific gravity (in the mass) is 2·84.

Blowpipe tests show the presence of chromium, so that the mineral is to be referred to chrome-mica or fuchsite.

Examined under a high power, the brown patches are found to owe their colour to minute included crystals, some twinned, and some simple, which have the characteristic form of rutile or zircon. Since they exhibit also lamellar twinning and do not give an absorption-spectrum, they are probably rutile.

The chief interest of the specimen is really archaeological; and this note is published with the object of directing the attention of mineralogists to the ancient use of this material as an ornamental stone, in the hope that they may see and identify similar specimens elsewhere. A polished piece showing no fracture would scarcely be identified as mica except by one who had seen this specimen or read a description of it. The substance is so beautiful when polished, and takes such a good surface, that it was probably a highly valued material. It has occurred to me that it may very possibly be one of the stones which received the name of emerald among the ancients.

Pliny distinguishes no less than twelve varieties of smaragdus; and it is quite clear that the name was applied to a number of green minerals. One variety in particular he describes in the following words[1]: 'Chalcedonii nescio an in totum exoleuerint, postquam metalla aeris ibi defecerunt; et semper tamen viles fuere, minimique. Iidem fragiles, sed colore incerti, et virentium in caudis pauonum columbarumque collo plumis similes, ad inclinationem magis aut minus lucidi, venosi quidem squamosique. Peculiare erat in his vitium sarcion appellatum: hoc est, quaedam gemmae caro. Mons juxta Calchedonem, in quo legebantur, Smaragdites vocatus est.'

Here the flaky structure, the iridescence or internal reflections, and the brown stain may all very well relate to a mineral similar to the one described in this note. That it had been brought from the neighbourhood of copper mines would suggest that it may have been a mineral

[1] 'Historia Naturalis,' Liber XXXVII, 18.

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which derived its green colour from copper; but this is by no means necessary.

King[1] identifies the chalcedonian smaragdus with 'crystals of transparent Chrysocolla,' an identification which will hardly recommend itself to mineralogists. Corsi[2] had supposed it to be the amazon-stone.

The use of fuchsite for decorative purposes in prehistoric times has been noted by Max Bauer[3], who found pierced beads from Guatemala to consist of this material.

Note on the Refractive Indices of Pyromorphite, Mimetite, and Vanadinite.

By H. L. Bowman, M.A.

[Read February 8, 1908.]

IT is somewhat remarkable that a group of minerals, of which such excellent transparent crystals are known as of pyromorphite, mimetite, and vanadinite, should not have hitherto been submitted to a detailed optical examination, except as regards the nature of the interference figures visible in a cross-section. The only reference to the refractive indices of these substances, which I have been able to find, is one by Schroeder van der Kolk[4], who states that those of pyromorphite and vanadinite are above 1·93 (as found by immersion in highly refracting liquids), and that they have a birefringence of 0·02 and 0·01 respectively.

The object of the present note is to record the results of some determinations of the refractive indices of the three minerals, made with material in the Oxford Museum from various localities, by means of the prism method.

Unfortunately the angle (60°) between alternate natural faces of the

[1] 'Natural History of Precious Stones and Metals,' 1883, p. 288.
[2] 'Delle Pietre Antiche,' Roma, 1828, p. 170.
[3] Centralblatt f. Mineralogie, 1900, p. 291.
[4] Zeits. anal. Chem., 1899, Jahrg. xxxviii, p. 656.

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hexagonal prism is too great to admit of the determination being carried out by their means, and so the following measurements have been made with prisms having at least one face artificially ground and polished, except in one case, in which, owing to the occurrence of faces of both m $\{10\bar{1}0\}$ and a $\{11\bar{2}0\}$, a convenient prism of 30° was available. The prisms used had in every case their edge parallel to the vertical axis of the crystal. They were made by grinding with oil on a sheet of ground glass (the crystal being cemented to a simple form of guide, which ensured the flatness of the faces), and were polished with putty-powder.

The exact position of the vertical axis within the crystals was somewhat uncertain owing to the striated and uneven character of the natural prism-faces, which frequently do not fall accurately into a zone, and a measurement of the angles between the ground faces and the basal plane (where present) was used to determine the accuracy of the orientation of the prisms, although this face also generally gave a blurred or multiple image in the goniometer.

Since, in a uniaxial crystal, any prism whose vertical bisecting plane contains the optic axis, will give the true values of ϵ and ω in the position of minimum deviation, any error (in ϵ) due to faulty cutting will depend only on the inclination of the optic axis to the plane bisecting the prism-angle. This inclination (θ) is given below for the various prisms, and (except in two cases) does not exceed $\frac{1}{2}$°—an amount which will scarcely affect the value of the index [1].

In the biaxial varieties the indices given under ϵ will correspond to α, while those given as ω will have a value intermediate between β and γ.

The indices were determined by the method of minimum deviation, for light of three colours, using—

Red glass,
Sodium flame,
Blue glass.

The last is a combination of a plate of 'signal green' with one of flashed blue glass, devised by H. G. Madan [2]. From the spectrum of direct sunlight it absorbs the whole of the red end as far as b, with the exception of a narrow band in the green, midway between D and E. The whole of the blue is transmitted, the brightest part being slightly beyond F. In most cases the source of light used was a Welsbach mantle, and the green

[1] If the true value of ϵ be calculated from the observed indices and θ, the result obtained in the worst case (No. 4) does not differ from the observed value by so much as one in the fourth place of decimals.

[2] Nature, 1885, vol. xxxi, p. 268.

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image was not seen; but in one case, with the electric arc, it was visible, and the corresponding indices are given (prism No. 2). The red glass transmits a well-defined band, whose centre is close to C.

Repeated readings for the deviation-angles were as a rule fairly concordant—the extreme values differing from the mean by less than 6′ to 7′—but in two cases the difference reached as much as 13′ (No. 1, ω_{Blue}) and 14′ (No. 4, ϵ_D). The maximum error possible in the refractive index (as compared with that calculated from the extreme readings) would then be 0·004, but the actual error is probably much less than this.

The values for red are the most reliable, while those for blue are the least certain, owing to want of light and the rather wide range of colour of the blue glass.

The material used for the various determinations is described below, and the results are collected in the table, p. 328.

It will be seen from the table that the substitution of arsenic for phosphorus, and of vanadium for arsenic, in each case causes an increase in the refractive indices.

(1) *Pyromorphite* from Braubach, Nassau.

A prism with two ground faces at 32° 17′[1], from a pale liver-coloured crystal (hexagonal prism with flat ends; forms[2]: *m*, *c*, *a*, *x*; *m* and *x* bright, *a* and *c* dull). $\theta = 0° 12'$[3].

This is a pure pyromorphite, and contains no arsenic or fluorine. On analysis it gave the following figures:

PbO	81·12
FeO (or Fe_2O_3) . . .	trace
P_2O_5	16·51
Cl	2·71
Ba, Ca	traces
	100·34
Less O for Cl . .	0·61
	99·73

[1] Each of the two faces gave two equally good images of the goniometer-signal 4′ apart. The prism-angles corresponding to these images are 32° 13′, 32° 17′, 32° 21′. The effective refracting angle is here taken as the mean (= 32° 17′). The difference in the refractive index caused by taking one of the extreme values would be about 0.0024.

[2] The lettering of the forms is that used by Dana (System, 1892), viz.:—*a* {11$\bar{2}$0}, *m* {10$\bar{1}$0}, *c* {0001}, *y* {20$\bar{2}$1}, *x* {10$\bar{1}$1}, *u* {21$\bar{3}$1}, *s* {11$\bar{2}$1}.

[3] θ = inclination of the optic axis to the plane bisecting the prism-angle.

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A cross-section of another similar crystal showed a uniform negative uniaxial figure over its whole area, with the exception of a narrow zoned border, which showed wavy extinction and (in places) a narrow-angled biaxial figure, with the axial plane at 90° or at 60° to an edge of the hexagon.

(2) *Mimetite* from Wheal Alfred, Cornwall (?).

A small crystal (1 mm. long), of a pale yellowish green colour, of unknown origin, but probably from Wheal Alfred. It shows the prism *m*, with two faces of *a*, and is terminated by *x* and a minute basal plane. The prism used was a natural one of 29° 58′ formed by a pair of plane and brilliant faces belonging to *a* and *m*.

(3) *Mimetite* from Wheal Alfred (?).

A prism of 86° 2′, with two ground and polished faces, made from a larger crystal off the same specimen as (2). Forms: *m*, *x*, *c*. $\theta = 0° 37'$.

(4) *Mimetite* from Wheal Alfred (?).

A pale green prismatic crystal with basal plane, having a bright yellow band at the free end. Locality uncertain, but probably Wheal Alfred. Forms: *m*, *c*, *y*, *x*. This must be referred to mimetite, as a small fragment (chiefly of the green material) showed only a trace of phosphoric acid.

The prism used had two ground faces at 30° 14′. $\theta = 1° 40'$.

A section (0·6 mm. thick) of the yellow end-material, cut perpendicular to the axis, shows a complex lamellated structure, and only extinguishes in places, in which traces of a negative biaxial figure are visible, having an axial angle $2E = 62°$, the axial plane being parallel to one or other of the sides of the hexagonal section. The lamellae appear to make an angle of about 40° with the hexagon-sides.

(5) *Mimetite* from Tintic District, Utah.

A prism of 30° 36′ with ground faces, from a slender, white, striated, hexagonal needle with broken ends. A natural prism-face is 40′ out of the zone of the two ground planes between which it lies.

Another crystal from the same specimen shows *m*, *x*, *c*.

A cross-section of a similar crystal shows a division into sectors and indistinct zonal structure. The sectors extinguish at 60° to the edges of the hexagon, and show a wide-angled negative bisectrix, with the axial plane in the same direction.

This specimen is a pure mimetite, being free from phosphoric acid.

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	Red (C)			Yellow (D)			Blue (F)		
	ϵ	ω	$(\epsilon-\omega)$	ϵ	ω	$(\epsilon-\omega)$	ϵ	ω	$(\epsilon-\omega)$
(1) Pyromorphite (Braubach)	2·042	2·0504	−0·0084	2·0494	2·0614	−0·0120	2·0832	2·0964	−0·0132
(2) Mimetite (Wheal Alfred?)	2·1236	2·1392	−0·0156	2·1346	2·1488	−0·0142	Green (D–E) 2·1780 Blue (F) 2·2053	2·1891 2·2220	−0·0161 −0·0167
(3) Mimetite („ „)	2·1180	2·1349	−0·0169	2·129	2·144	−0·015	2·1762	2·1915	−0·0153
(4) Mimetite („ „)	2·1178	2·1344	−0·0166	2·129	2·1475	−0·0185	—	—	—
(5) Mimetite (Tintic)	2·1178	2·1326	−0·0148	2·1286	2·1443	−0·0157	2·1750	2·1932	−0·0182
(6) Endlichite (Hillsboro')	2·292	2·341	−0·049	2·311	2·358	−0·047	—	—	—
(7) Vanadinite (Tucson)	2·299	2·354	−0·055	—	—	—	—	—	—

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It is probably similar to the material from the Richmond Mine, Eureka, Nevada, analysed by Massie[1].

(6) *Endlichite* from Hillsboro', New Mexico.

A prism of 31° 8′ with two ground faces, cut from a pale yellow hexagonal prism (2·5 mm. diam.) with basal plane and narrow faces truncating the vertical edges. The basal plane gave several images, and the angles from it to the ground planes varied between 89° 51′ and 90° 30′ and between 89° 35′ and 90° 7′. Taking the mean values, $\theta = 0° 11'$. The natural prism-faces do not fall into a zone.

A cross-section (0·8 mm. thick) of another crystal from the same specimen, does not extinguish in any position, but shows in places a banded structure, suggesting zones of varying composition. Most of the section shows a normally emergent negative bisectrix ($2E = 14°$). The axial plane varies in position in different parts of the section, being in some places parallel to a face of a hexagonal prism, and in others inclined to it at various angles.

(7) *Vanadinite* from the Old Mammoth Mine, Tucson, Arizona.

A prism of 21° 10′ with one ground and one natural face, from a dark ruby-red crystal (hexagonal prism with flat ends, *m*, *c*, *u*). [Some other crystals off the same specimen show *m* and *c*, narrow *x*, and minute planes of *u*, *s*.] $\theta = 0° 24'$.

The indices were determined for the nearly monochromatic red light transmitted by the crystal, which lies between the lines C and D.

The crystal is markedly pleochroic, the colours being:—

ω brownish-red.

ε brownish-yellow.

Note on some rare twins of Calcite from Somerset.

By H. L. Bowman, M.A.

[Read February 4, 1902.]

THE crystals to which this note refers, occur in a quarry in the New Red Sandstone at Bindon, in Somerset, on the property of Mr. H. H. Worthington, and were presented to the Oxford Museum a few months ago by his son, Mr. J. H. Worthington. I have lately had an opportunity of visiting the locality and examining the mode of occurrence of the specimens.

[1] Chem. News, 1882, vol. xlvi, p 215.

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The crystals have all been obtained from a single, roughly vertical vein in the side of the quarry, which shows an exposure of irregularly alternating beds of red sandstone and conglomerate. The pebbles of the latter consist, for the most part, of a compact purplish limestone, while a few are of greasy-looking quartz. The vein is at present traceable to a vertical height of about nine feet from the floor of the quarry, and has an average width of about six inches, but in some places it is much narrower and filled up with masses of calcite.

The crystals are thickly scattered over both walls of the vein, and are of two sizes, the larger being uniformly twins of the habits shown in figs. 1 and 2, and usually about one inch in thickness, and as much

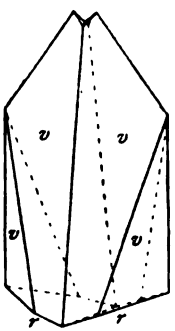

FIG. 1.

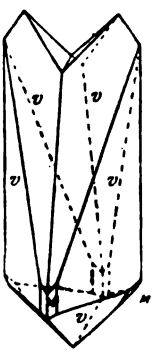

FIG. 2.

Calcite from Somerset. Twin-plane f (11$\bar{1}$).

as two inches long. These are sometimes accompanied by smaller, rounded-scalenohedral crystals, about $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter, which are not twinned. The crystals are enveloped in red clay, of which they enclose portions, and are thereby stained red.

The interest of the occurrence lies in the twinning, which takes place according to the rarest of the twin-laws of calcite, the twin-plane being the face f (11$\bar{1}$).

The faces of the crystals are dull, and often pitted and cavernous, but measurement of good specimens with the contact-goniometer shows the main scalenohedron to be the common form v {20$\bar{1}$}, while one doubly terminated specimen (fig. 2) shows also faces of a steep direct rhombohedron, probably M{3$\bar{1}$1} [Dana's {40$\bar{4}$1}]. The crystals are commonly attached by one end to the matrix, and when broken off show a pair of cleavage-planes forming an obtuse (salient) angle of 85½° (fig. 1). One crystal gave on measurement 85° 30′, the theoretical angle being 85° 27′.

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On some crystals of Quartz from De Aar (Cape Colony) and other localities.

By T. V. Barker.

[Communicated by Professor Miers, and read February 3, 1903.]

A SMALL set of quartz crystals of somewhat peculiar habit, collected by Lieut. E. G. Spencer-Churchill near De Aar, South Africa, and given by him to the Mineral Department of the University Museum, present some features of interest; two crystals, in particular, are remarkable as exhibiting faces seldom observed on quartz. The first has a face X lying in the zone $[mz]$ (or $[mr]$?), the other a well-developed face in the zone $[rz]$.

The crystal bearing the former face, X, is depicted in fig. 1. As regards habit and other features, it is in all respects similar to the second crystal (fig. 2).

The faces r and z cannot be distinguished with certainty, but cleavage-cracks within the crystal point to the lettering shown in fig. 1. The polariscope proves the presence of both right- and left-handed material.

The face X gave on the goniometer two indifferent images (X_1, X_2), neither of which could be preferred to the other; the measured angle leads to the indices $(77\bar{5})$ and $(33\bar{2})$ if the faces are below z, or to $(11.\bar{1}.1)$ and $(14.\bar{1}.1)$ if they are below r. All four faces have been found by Des Cloizeaux on crystals from Traversella.

	Angle to m. Observed.	Calculated.	Miller.	Bravais.	Des Cloizeaux.
X_1	30° 14′	30° 34′	$(77\bar{5})$ or $(11.\bar{1}.1)$	$(\bar{4}403)$ $(04\bar{4}3)$	$e^{\frac{5}{2}}$ e^{11}
X_2	32° 13′	32° 12½′	$(33\bar{2})$ or $(14.\bar{1}.1)$	(5504) (0554)	$e^{\frac{3}{2}}$ e^{14}

The other crystal is exhibited in fig. 2. The habit is slightly tabular parallel to r. The crystal is somewhat smoky and contains liquid inclusions, one of which shows a bubble. The surface is much corroded. There is no marked cleavage, and the crystal does not exhibit any s-faces. It is therefore not possible to identify r and z. On immersion in oil and examination in convergent polarized light, the crystal exhibits Airy's spirals, and is therefore an interpenetration-twin of right- and left-handed

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material; the right-handed portion, however, appears to predominate. The lower end of the crystal is broken.

There is a single face on an edge [*rz*], which lies to the left of a rhombohedron-face, and corresponds to d_4 (18.$\bar{1}$.2) (18.11.$\bar{1}\bar{4}$.14) or to its inverse ($\bar{1}$1.31.22) (3.$\bar{1}$1.14.14). Measurement of the angle between this face, which is slightly rounded and gives a small band of images,

FIG. 1.

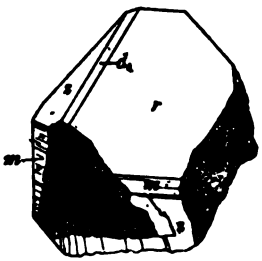

FIG. 2.

Quartz crystals from De Aar, Cape Colony.

and the rhombohedron-face, *r* or *z*, gave, as the mean observed value, 9° 30′, the corresponding calculated value being 9° 25′.

FIG. 3.—Quartz. (Locality unknown.)

The face d_4 was first observed by Websky[1] on a crystal of unknown origin; on this crystal, too, it was not accompanied by any other face of this series. The inverse form does not appear to have been observed.

The other crystals from this locality contain liquid inclusions, in small spaces which are either negative crystals or flattened cavities; and the crystals, when broken, yield a smell somewhat resembling that of petroleum.

On examining other crystals in the Oxford collection, one of unknown locality was found, also showing faces in the zone [*rz*]. It is depicted in fig. 3. The lower end of the crystal is broken away by cleavages parallel to the rhombohedron *r*; the *m*-faces are horizontally striated. The face *s* is present (at the back of the crystal), and its

[1] Ann. Phys. Chem. (Poggendorff), 1856, vol. xcix, p. 296.

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position with respect to r proves the crystal to be left-handed. To the left of z, at M in the figure, there is a re-entrant angle. The r-faces are smooth, the z-faces rough. The lower end of the crystal is opaque, so that optical observations were not possible without mutilation.

The zones $[rz]$ are corroded, some of the corrosion-faces giving distinct images, while there is also a band of images approximating to a face β (20.7.14). The faces occur on two edges $[rz]$—A and B, and the measured angles between them and r are given in the following table, together with the corresponding calculated angles and indices. The angles are calculated for an axial ratio $a:c = 1:1{\cdot}09997$ ($rr' = 85°\ 46'$).

Face.	$(hkl):100$. Observed.	$(hkl):100$. Calculated.	Miller.	Bravais.
	On the edge A.			
	° ′	° ′		
ϕ_1	13 48	13 50	121.$\bar{1}$4.28	14.31.$\bar{4}$5.45
ξ	22 52	23 8	5$\bar{1}$2	1122
ϕ_2	27 44	27 48	77.$\bar{1}$9.38	19.13.$\bar{3}$2.32
ξ_4	33 38	33 30	16.5.10	5277
A band of faces	35 5 to 38 13	35 11 to 38 14	8$\bar{1}$2 to 88.3$\bar{1}$.62	3$\bar{1}$44 to 31.7.3$\bar{3}$.38
β (centre of the band)	36 39	36 29	20.7.14	7299
β_6	43 40	43 38	11.5.10	15.1.$\bar{1}$6.16
ϕ_4	44·49	44 46	19.9.18	27.1.$\bar{2}$8.28
ϕ_5	45 29	45 28	35.$\bar{1}$7.34	51.1.$\bar{5}$2.52
	On the edge B.			
ϕ_2	27 46	27 48	77.$\bar{1}$9.38	19.13.$\bar{3}$2.32
A band of faces	34 27 to 37 26	34 27 to 37 26	149.$\bar{3}$7.94 to 257.9$\bar{1}$.182	141.55.$\bar{1}$96.196 to 91.25.$\bar{1}$16.116

It is noteworthy that we have a band of images about β in both cases. ξ was first observed by Des Cloizeaux, ξ_4 by Gonnard, β by Des Cloizeaux, and β_6 by Gonnard.

The crystal appears to be very similar to some described by Lacroix [1], in which the surfaces between r and z were curved and gave sometimes separate images, sometimes groups of images. Thus on a crystal from Allevard in the department of Isère, he found images indicating faces inclined to r at angles varying between the values 9° 30′ and 11° 0′; also between 22° 0′ and 27° 2′: finally, the faces β_1 (8$\bar{1}$2) and β_6 (11.5.10) gave distinct images. Again, a crystal from La Gardette showed a large undulating surface with triangular cavities. The author

[1] 'Minéralogie de la France,' 1901, Tome iii, Fasc. 1, p. 100.

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observes that—'It gives almost uninterrupted reflections between H_0 and ξ, which are most clear in the neighbourhood of H_1. These are without doubt due to natural corrosion.'

The following is a list, partly compiled from that given by Gonnard[1], of the faces hitherto observed between r and z in the zone $[rz]$ on quartz. The indices are here all given as for faces lying to the left of r or to the right of z.

Symbol.	Calc. angle $(hkl):(100)$.	Miller.	Bravais.	Observer[2].
d_{10}	3° 1′	41.1.2	1.13.$\bar{1}$4.14	Websky.
γ_3	3 16	38.1.2	1.12.$\bar{1}$3.13	vom Rath.
d_9	4 16	29.1.2	1.9.$\bar{1}$0.10	Websky.
d_8	5 22	23.1.2	1788	,,
d_7 / H	7 14	17.1.2	1566	Websky. / Des Cloizeaux.
d_6 / H_0	8 11	15.1.2	8.13.$\bar{1}$6.16	Websky. / Gonnard.
d_5 / H_1	8 45	14.1.2	1455	Websky. / Des Cloizeaux.
d_4	9 25	13.1.2	8.11.$\bar{1}$4.14	Websky.
d_3 / H_2	11 5	11.1.2	1344	Websky. / Des Cloizeaux.
γ_{11}	12 9	10.1.2	8.8.$\bar{1}$1.11	vom Rath.
d_2	13 26	9$\bar{1}$2	8.7.$\bar{1}$0.10	Websky.
ϕ_1	13 50	121.$\bar{1}$4.28	14.31.$\bar{4}$5.45	Barker.
H_4	14 21	42.5.10	15.32.47.47	Gonnard.
d_1 / γ	15 2	8$\bar{1}$2	·1238	Websky. / Des Cloizeaux.
H_5	19 38	6$\bar{1}$2	3477	Gonnard.
H_6	22 9	21.4.8	12.13.25.25	,,
ξ	23 8	5$\bar{1}$2	1122	Des Cloizeaux.
ξ_1	26 38	17.4.8	4377	Termier.
ϕ_2	27 43	77.$\bar{1}$0.38	19.13.32.32	Barker.
γ_0	28 1	4$\bar{1}$2	3255	Termier.
ξ_2	29 14	19.5.10	5388	Gonnard.
ξ_3	30 32	18.5.10	15.8.23.23	,,
γ_1	31 14	7$\bar{2}$4	2133	Des Cloizeaux.
γ_2	32 50	23.7.14	7.3.$\bar{1}$0.10	,,
ξ_4	33 30	16.5.10	5277	Gonnard.
β	35 11	3$\bar{1}$2	3144	vom Rath.
β_1	36 29	20.7.14	7299	Des Cloizeaux.
γ_4	40 6	5$\bar{2}$4	6177	Gonnard.
β_5	41 14	12.5.10	15.2.$\bar{1}$7.17	,,
β_6	43 38	11.5.10	15.1.$\bar{1}$6.16	,,
ϕ_4	44 46	19.9.18	27.1.$\bar{2}$8.28	Barker.
ϕ_5	45 28	35.$\bar{1}$7.34	51.1.52.52	,,

[1] Bull. Soc. franç. Min., 1902, vol. xxv, p. 62.

[2] Authorities cited in the table:—

M. Websky, Ann. Phys. Chem. (Poggendorff), 1856, vol. xcix, p. 296; and Neues Jahrb. Min., 1871, p. 908.

A. Des Cloizeaux, Ann. Chim. Phys., 1855, ser. 3, vol. xlv, p. 129; and 'Mém.

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It appears from the statements of previous authors, and from my own observations, that of the above faces d_{10}, ϕ_1, H_4, H_5, H_6, ϕ_3, γ_0, ξ_2, ξ_4, β_5, β_6, ϕ_4, and ϕ_5 occur on the left of r, their indices being of the form $\{h\bar{l}k\}$, where $k = 2l$; while γ_3, $H(d_7)$, $H_0(d_6)$, $H_1(d_5)$, $H_2(d_3)$, ξ_1, β_1, and γ_4, lie on the right of r, their indices being of the form $\{hk\bar{l}\}$; finally, γ_{11}, d_2, $\gamma(d_1)$, γ_1, and β occur both on the right and left of r. It is impossible to determine the positions of the remaining forms.

Gonnard[1] identifies his face γ_0 (8255) with a face Γ_1 (82.17.15.62) found by Termier. It may be seen, however, that Γ_1 does not lie in the zone $[rz]$. The error probably arose from the similarity of angles. $[r\Gamma_1 = 28° 14', r\gamma_0 = 28° 20'$ (observed values)].

Again in fig. 2[2] of crystal *A* (quartz from Meylan) the faces ξ_2, H_5, β_6 appear to be wrongly lettered, since the order of the faces in the zone should from the indices be z, β_6, ξ_2, H_5.

In two cases Gonnard[3] describes as 'dextrogyre,' crystals showing *s*-faces with left-handed striations, and again on p. 112 he seems to invert the ordinary use of the terms right- and left-handed.

The relative position of the Millerian and Bravais axes used above, is that adopted by Professor Miers[4] and Professor Lewis[5], in which the lateral hexagonal axes *xyz* are perpendicular to the planes containing the vertical axis *w* and the rhombohedral axes *XYZ* respectively. The axes *XYZ*, *xyz* (seen from above) are arranged counter-clockwise—the order being $+x$, $-z$, X, $+y$, $-x$, Y, $+z$, $-y$, Z.

sur la crist. et la structure intérieure du quartz' (Mém. prés. à l'Acad. Paris, 1858, vol. xv).

G. vom Rath, Zeits. Kryst. Min., 1881, vol. v, p. 1; and 1885, vol. x, p. 156.

P. Termier, Bull. Soc. franç. Min., 1895, vol. xviii, p. 443.

F. Gonnard, Bull. Soc. franç. Min., 1899, vol. xxii, pp. 92, 94; and 1902, vol. xxv, pp. 56, 90.

[1] Bull. Soc. franç. Min., 1902, vol. xxv, p. 61.

[2] Bull. Soc. franç. Min., 1899, vol. xxii, p. 97.

[3] Ibid., p. 98, fig. 1, and p. 124, fig. 1.

[4] Mineralogy, 1902, p. 66.

[5] Crystallography, 1899, p. 454.

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Sulpharsenites of lead from the Binnenthal. Part IV.—Seligmannite: with a supplementary note on Baumhauerite.

By R. H. Solly, M.A.

[Read November 18, 1902.]

Seligmannite.

Professor Baumhauer[1], in January, 1901, described five very small crystals of a new mineral, to which he gave the name seligmannite. They were associated with rathite and binnite in dolomite, and came from the Lengenbach quarries in the Binnenthal, Switzerland. In June, 1902, he[2] described another crystal, the angles of which agreed fairly well with those of the crystals he had previously measured. In habit and twinning, these orthorhombic crystals so closely resembled bournonite that he ventured to assign to the new mineral the chemical formula $Cu_2S.2PbS.As_2S_3$, but from paucity of material he was unable to make a chemical analysis.

In September, 1902, I received from Binn four specimens of dufrenoysite, on which were deposited a number of minute but very brilliant crystals. The largest crystal measured $2 \times 1\frac{3}{4} \times \frac{3}{4}$ mm., and the others varied from $\frac{1}{4}$ to 1 mm. Twelve small crystals were removed for measurement, and proved to be this new mineral, seligmannite. A qualitative analysis of four of these crystals performed, under the kind direction of Mr. H. J. H. Fenton, in the University Chemical Laboratory at Cambridge, proved the presence of copper, lead, sulphur, and arsenic. It is, therefore, highly probable that when more crystals are available for quantitative analysis, the chemical composition of this mineral will be found to be the one suggested by Baumhauer on the grounds of its crystallographic isomorphism with bournonite.

The elements deduced from the crystallographic determination of these twelve crystals differ slightly from those obtained by Baumhauer:—

$$a:b:c = 0{\cdot}92804 : 1 : 0{\cdot}87568 \text{ (Baumhauer)},$$
$$a:b:c = 0{\cdot}92832 : 1 : 0{\cdot}87838 \text{ (Solly)}.$$

[1] Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, p. 110; abstract, this vol., p. 205.

[2] Ibid., 1902, p. 611.

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The latter ratios were calculated from (011) : (001) = 41° 8′, (100) : (101) = 46° 35½′, and (010) : (120) = 28° 26′. These angles were measured on the best crystals, and the reflections were very sharp.

The crystals are all twinned about (110) and some about (1̄10).

	Calculated.	Measured.	
	Solly.	Solly.	Baumhauer.
$110 : \overline{1}\overline{1}0$	9° 8′	9° 8′	8° 41′, 8° 54′
$111 : \overline{1}\overline{1}\overline{1}$	7 13	7 13	6° 48½′.

The (100), (010), and (001) planes are usually well developed. The plane (110) is always large and striated parallel to its intersection with the planes (100) and (111); besides these striations there are sometimes fine striae parallel to the zone-axis [1̄11], but not parallel to the zone-axis [11̄1] as would be required by the symmetry of the crystal. The planes (111), (101), (011), and (112) are often well developed.

The colour of the mineral is lead-grey; the lustre is metallic and brilliant; the streak, chocolate-colour. The mineral is opaque. No cleavage was observed. Fracture, conchoidal. Hardness, 3. Specific gravity, not determined, owing to lack of material.

List of Forms observed on Seligmannite.

Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.
a	100	Baumh.	*z*	021	Baumh.	*C*	311	Baumh.
b	010	,,	*n*	011	,,	*v*	211	,,
c	001	,,	¾*κ*	025	Solly	*D*	322	Solly
i	180	,,	*κ*	013	Baumh.	*u*	112	Baumh.
f	120	,,	*o*	101	,,	*φ*	113	Solly
m	110	,,	*x*	102	Solly	½*p*	229	,,
e	210	,,	*ε*	103	,,	3*p*	331	,,
η	310	Solly	*t*	104	,,	4*p*	441	,,
A	410	Baumh.	Δ	105	,,	*ι*	218	Baumh.
q	510	,,	*ρ*	121	Baumh.	*W*	431	,,
B	071	,,	*y*	111	,,	*O*	1.10.2	,,
Σ	031	,,	*s*	212	Solly			

The total number of forms is thirty-five, of these twenty-three were recorded by Baumhauer. The twelve new forms are all well developed. I have not observed Baumhauer's (021), (031), (071), and (1.10.2).

Below are given the calculated angles and the best measurements from the twelve crystals; also the smallest and greatest angles obtained by Baumhauer between similar planes.

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Calculated and measured Angles of Seligmannite.

	Calculated.	Measured.			
	Solly.	Solly.		Baumhauer.	
Zone [100,010].					
100 : 510	10°27½′	10°28′		9°57½′	
: 410	13 0	12 59	13° 0′	13 2½	
: 310	17 6½	17 6	17 8		
: 210	24 47	24 47	24 48	24 50½	24° 54′
: 110	42 43	42 43	42 44	42 36	42 47
: 120	61 34	61 34		61 37½	61 50½
: 130	70 9	70 10		70 34	
: 010	90 0	90 0		89 48½	90 2
Zone [100,001].					
100 : 101	46 35½	46 35½		46 35½	46 44
: 102	64 41½	64 40	64 41		
: 103	72 30	72 28			
: 104	76 41½	76 41			
: 105	79 17	79 15			
Zone [001,010].					
001 : 013	16 14	16 14		16 14¼	
: 025	19 15½	19 15½			
: 011	41 8	41 8		41 7½	41 20
: 021	60 16			60 21	
: 031	69 6½			67 44½	69 41
: 071	80 42½			80 36½	80 37½
: 010	90 0	90 0			
Zone [001 110].					
001 : 229	15 58	15 58			
: 118	23 13½	23 15			
: 112	32 46	32 46		32 44	32 51½
: 111	52 9½	52 9		52 8	52 23
: 331	75 29	75 30			
: 441	79 0½	79 0			
: 110	90 0	90 0		90 0	
Zone [001,210].					
001 : 213	34 46½	34 46			
: 212	46 10	46 10			
: 211	64 21½	64 21		64 24½	64 27½
: 210	90 0	90 0			

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	Calculated.	Measured.		
	Solly.	Solly.	Baumhauer.	
Zone [100,011].				
100 : 311	25° 4½′	25° 0′	25° 9½′	
: 211	35 3½	35 4	34 54	35° 5½′
: 322	43 6	43 8		
: 111	54 32	54 32	54 35½	54 36
: 011	90 0	90 0		
Zone [010,101].				
010 : 121	38 14½	38 14½	37 59	38 16¾
: 111	57 36½	57 36½	57 33½	57 35½
: 212	72 24	72 24		
: 101	90 0	90 0		
Zone [110,101].				
110 : 431	14 37	14 37	14 20	
: 211	30 56½	30 56½	30 50	30 54½
: 101	59 41	59 41	59 42½	59 48½
: 2$\bar{1}$3	77 24	77 23		
: 1$\bar{1}$2	87 32	87 32		
: 0$\bar{1}$1	116 30	116 30	116 29½	116 37½
: $\bar{1}$21	147 42	147 42	147 50	
: $\bar{1}\bar{1}$0	180 0	180 0		
001 : 121	62 49	62 50	63 23½	
001 : 431	77 44	77 44	77 6½	
010 : 1.10.2	14 13½		14 13¼	
101 : 0$\bar{1}$1	56 49	56 49		

Baumhauerite [1].

In September, 1902, some fine specimens of this recently discovered mineral were found in the Lengenbach quarries in the Binnenthal. The largest crystal measured 25 × 20 × 10 mm.; the colour is steel-grey with very brilliant lustre; and the habit is slightly different from that of the crystals previously described. The difference lies in their polysynthetic growth: the crystals are completely penetrated by numerous, very thin twin-lamellae, closely resembling those parallel to (074) of rathite [2]; further, there is twinning with (100) as twin-plane and face of union.

[1] The following note, which has already appeared in Zeits. Kryst. Min., 1903, vol. xxxvii, pp. 329–331, pl. V, fig. 5, is supplementary to Part III ('Baumhauerite, a new mineral.' This vol., 1902, pp. 151–160) of this series of papers on the sulpharsenites of lead from the Binnenthal.

[2] This vol., p. 80.

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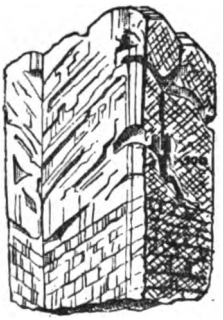
The accompanying figure is an exact representation of such a polysynthetic group, showing the twinning on (100) and the twin-lamellae. The cohesion existing between the individual crystals is so slight that the warmth of the hand will cause them to fly apart, and the fresh surfaces which are formed, instead of consisting of cleavage-planes or uneven surfaces, are composed of a number of very brilliant pyramid-faces.



Polysynthetic crystal of Baumhauerite.

In rathite the plane parallel to the twin-lamellae lies in a zone containing two of the axial planes, whereas in baumhauerite it is inclined to such a zone. It was impossible on my Fuess goniometer to do more than determine that the plane did not lie in the zone [100, 010], but Mr. G. F. Herbert Smith kindly measured some of the crystals on the British Museum three-circle goniometer, and found that the plane would have indices approximating to (76$\bar{1}$).

The following is a list of the twenty-five new forms which were observed on six crystals, and have to be added to the ninety-five already recorded. The forms (706), (503), (805), (308), and (103), previously observed only by Baumhauer, were also present on these crystals.

$-25\,h$ (25.0.1)	$-\frac{7}{2}\,h$ (702)	$+\frac{13}{4}\,h$ (13.0.$\bar{4}$)	$+\frac{5}{6}\,g$ (50$\bar{9}$)
$-19\,h$ (19.0.1)	$-3\,h$ (301)	$+\frac{11}{4}\,h$ (11.0.$\bar{4}$)	$+\frac{1}{6}\,g$ (10$\bar{6}$)
$-\frac{19}{2}\,h$ (19.0.2)	$+\frac{15}{2}\,h$ (15.0.2)	$+\frac{9}{4}\,h$ (90$\bar{4}$)	$+\frac{1}{7}\,g$ (107)
$-9\,h$ (901)	$+7\,h$ (70$\bar{1}$)	$+\frac{11}{6}\,h$ (11.0.6)	$+\frac{1}{12}\,g$ (1.0.$\bar{12}$)
$-\frac{17}{2}\,h$ (17.0.2)	$+6\,h$ (60$\bar{1}$)	$+\frac{4}{3}\,h$ (403)	
$-\frac{15}{2}\,h$ (15.0.2)	$+\frac{9}{2}\,h$ (90$\bar{2}$)	$+\frac{5}{4}\,h$ (50$\bar{4}$)	
$-4\,h$ (401)	$+\frac{7}{2}\,h$ (702)	$+\frac{5}{6}\,g$ (506)	

The table below gives the calculated angles and the best measurements obtained from the six crystals which were measured.

	Calculated.	Measured.		
Zone [100,001].				
100 : 25.0.1	3°15½′	3°14′	3°12′	3°16′
: 19.0.1	4 16	4 20	4 12	4 18
: 19.0.2	8 14	8 15	8 14	8 16
: 901	8 52	8 54	8 50	8 53
: 17.0.2	9 22	9 23	9 21	9 22
: 15.0.2	10 34	10 33	10 32	10 33
: 401	18 54	18 56	18 54	18 55

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	Calculated.	Measured.		
: 702	21°15½′	21°14′	21°14′	21°15′
: 801	24 14	24 12	24 12	24 15
100 : 15.0.2	11 5	11 4	11 4	11 5
: 701	11 52½	11 52	11 53	11 52
: 601	13 50	13 50	13 49	13 50
: 902	18 21½	18 22	18 21	18 22
: 702	23 22	23 24	23 22	23 24
: 13.0.4	25 2½	25 1	25 2	25 3
: 11.0.4	29 10	29 10	29 10	29 9
: 904	34 44	34 45	34 44	34 45
: 11.0.6	40 58½	40 58½	40 59	40 58½
: 403	51 15	51 15		
: 504	53 20	53 20	53 21	
: 506	65 35½	65 30	65 37	
: 509	75 25½	75 30	75 24	
: 106	90 40	90 40	90 40	90 39
: 107	91 37	91 35	91 37	91 36
: 1.0.12	93 59	93 59		

ERRATA.

The following baumhauerite forms (this vol., pp. 153, 156, 159) require correction :—

For $+ \frac{3}{13} g$ 2.0.13 read $+ \frac{3}{11} g$ 2.0.11
„ $+ \frac{1}{8} g$ 109 „ $+ \frac{1}{8} g$ 108
„ $+ \frac{1}{13} g$ 1.0.12 „ $+ \frac{1}{10} g$ 1.0.20

Page 156. For 100 : 1.0.12 = 95°12½′ read 100 : 1.0. 20 = 95°18½′ (calculated).
FIG. 1 (p. 152). For 100 (at top of figure) read 108.

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On the Diathermancy of Antimonite.

By A. Hutchinson, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Read March 24, 1908.]

A DETERMINATION of the constants of elliptic polarization of light reflected from a fresh cleavage surface of antimonite enabled Professor P. Drude [1] to calculate two of the indices of refraction of this substance as 5·17 and 4·49 respectively. Instead, however, of the symmetry-axes of the crystal, regarded as belonging to the orthorhombic system, coinciding with the principal vibration directions in the plane (010), he found that the latter were inclined to the former lines at angles which varied in different observations between 2·6° and 15·4°. These observations, which indicate that the symmetry of antimonite is of the oblique or anorthic type [2], stand in opposition to those of Professor O. Mügge [3], who found that exceedingly thin flakes of antimonite placed between crossed nicols in direct sunlight transmitted sufficient light of a deep red colour to enable him to determine the extinction as straight.

As, however, the morphological and physical characters of antimonite taken as a whole, are those of an orthorhombic crystal, it seemed desirable to find, if possible, some new method of testing the transmission of radiant energy by crystalline substances, such as antimonite, which are opaque to light. A clue to such a method was found in an observation of Schultz-Sellack [4], who showed, some thirty years ago, that zinc-blende was very diathermanous, and that artificial sulphide of arsenic possessed the same property though to a less extent. It seemed probable therefore that antimonite might also be sufficiently diathermanous to enable its behaviour towards radiations of long wave-length to be determined, and to thus afford data on which conclusions as to its crystal-system might be based. On trial this proved to be the case, and the behaviour of a thin cleavage flake of antimonite was found to be consistent with orthorhombic symmetry [5].

[1] Ann. Phys. Chem. (Wiedemann), 1888, vol. xxxiv, p. 489.

[2] Loc. cit., p. 527.

[3] Neues Jahrb. Min., 1898, vol. i, p. 12.

[4] Ann. Phys. Chem. (Poggendorff), 1870, vol. cxxxix, p. 182.

[5] Since this paper was written E. C. Müller has published an elaborate investigation entitled 'Optische Studien am Antimonglanz,' Neues Jahrb. Min., 1908, Beil.-Bd.

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Apparatus and mode of experimenting.—The source of radiation was an ordinary lime-light fed with coal-gas and oxygen. The radiation from the incandescent lime was focused on the thermo-couple of a Boys' radiomicrometer, placed at a distance of about 75 cm. from the lime, by means of a quartz lens 5 cm. in diameter and 9 cm. focal length. A microscope, provided with a rotating stage graduated in degrees, was fixed between the lens and the radiomicrometer. The tube of the microscope was placed horizontally and all the lenses removed. To adjust the flake of antimonite on the rotating stage, the flake was either placed between two pieces of cardboard in which holes had been made or else fastened by a little wax to a very thin piece of glass (a cover-slip). The latter proved to be the more convenient arrangement, as the amount of radiation stopped by the glass was found to be inappreciable. Before reaching the antimonite the heat-rays were polarized by passing through an ordinary nicol prism fitted in the substage of the microscope-stand. This prism was 5 cm. long and measured 2·5 cm. along the short diagonal of the end face. On the other side of the antimonite plate an analyser was fitted in the tube of the microscope: this was a square-ended prism measuring $4{\cdot}5 \times 1{\cdot}7 \times 1{\cdot}7$ cm.

The radiomicrometer, consisting of an antimony-bismuth couple suspended by a quartz fibre between the poles of a permanent magnet, was of the pattern described by Mr. Boys[1], and belongs to the Cavendish Laboratory. It is a very sensitive and trustworthy instrument, and I am greatly indebted to Professor J. J. Thomson for the loan of it[2]. The position of the image reflected from the mirror of the radiomicrometer was determined by means of a centimetre scale bent into a circular arc of 113 cm. radius, having for centre the position of the mirror. The readings were taken to 1 mm. and the maximum deviation observed, amounting to 18 cm., corresponds to a rotation of the radiomicrometer mirror through approximately 5°. Great care was taken to protect the radiomicrometer from stray radiations by means of suitable screens, and from vibration by mounting it on india-rubber blocks supported on a solid stone shelf built into the wall of the room in which the experiments were made, but in spite of these precautions the vibrations caused

xvii, pp. 187-251. This research, conducted by methods similar to those employed by Drude (loc. cit.), has led Müller to conclude that Drude was mistaken in attributing oblique or anorthic symmetry to antimonite, as all his own results are consistent with the view that antimonite crystallizes in the orthorhombic system.

[1] Phil. Trans. Roy. Soc., 1889, vol. clxxx, p. 159.

[2] I desire here to record my thanks to my friend Mr. Skinner, of the Cavendish Laboratory, for much kind help in setting up apparatus.

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by traffic in the neighbouring street were a source of much inconvenience.

The arrangements, then, were essentially the same as those employed for examining crystal sections in parallel plane polarized light, the thermo-couple of the radiomicrometer being substituted for the observer's eye. It was found on trial that when the nicols were crossed no measurable radiation reached the radiomicrometer: on the other hand, when their principal planes were parallel the effect produced was so great that the spot of light instantly travelled off the scale.

A thin cleavage flake was next prepared from a crystal of Japanese antimonite. It proved on measurement to be 0·29 mm. thick. In some experiments the whole area of the plate (35 to 40 sq. mm.) was employed, in others it was limited to 20 sq. mm. by holes cut in the cardboard mount. The direction of the symmetry-axes lying in the cleavage face (010) can be easily identified either by the bounding edges made by planes belonging to the zone [100,010], or by the striae due to the presence of slip-planes lying in the zone [010,001]. By means of these striae the plate was brought into a definite position in the following way:—the tube of the microscope was fitted with a low power objective and with an eyepiece provided with cross-wires. The nicols were crossed and a quartz crystal adjusted on the stage so as to be in the position of extinction when the circle reading was 0°. The cross-wires were placed respectively parallel and perpendicular to the axis of the quartz crystal, which was then removed and replaced by the antimonite; this was in its turn adjusted till one of the cross-wires coincided with the striae. The eyepiece and objective were then removed, leaving the nicols untouched.

Now, since the striae on (010) are parallel to the brachy-axis of the crystal, and since these striae have been set to coincide with one or other of the vibration directions of the nicols, it follows that if the crystal is really orthorhombic the flake is in the position of extinction, and that on allowing the radiation to fall on it no indication should be given by the radiomicrometer, while on turning the flake in its own plane heat should be transmitted, the amount reaching a maximum for rotations of 45° from the zero position. On trial these predictions were found to be completely verified and the orthorhombic symmetry of antimonite confirmed.

Results.—The results obtained may be illustrated by the following figures:—

Circle:	0°	10°	20°	30°	40°	45°	50°	60°	70°	80°	90°.
Scale:	0	2	7½	13½	17½	18	17½	13	6½	1½	0.

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Under the heading 'circle' are given the readings of the graduated stage to which the antimonite was attached; the readings being 0° or 90° when the vibration directions in the plate, as determined by the striae, coincided with the vibration directions of the nicols. Under 'scale' are given the corresponding deflections in cm. of the spot of light on the scale of the radiomicrometer, and these may be taken as directly proportional to the amount of heat transmitted.

These observations, while supporting those of Professor Mügge, stand in opposition to those of Professor Drude, as the results obtained by the latter require that the plate should transmit radiation when set in the position above described, but should cease to do so after being turned through an angle varying from 2° to 15°.

An attempt was made to determine the intensity of the radiation transmitted at every 10° during a complete rotation of the plate in its own plane. It was not, however, found possible to keep the source of radiation sufficiently constant during the rather considerable time requisite for taking the necessary readings. The results may be most conveniently exhibited by plotting them on squared paper. When this is done and a curve drawn, it is noticed that in the neighbourhood of the maxima and minima of heat transmission an alteration of 5° in the azimuth of the crystal plate makes hardly any difference in the reading of the radiomicrometer, and therefore it may be objected that the sensitiveness of the method is not sufficient to fix within 5° or even 10° the position of the principal vibration directions in the plate. This difficulty can be overcome by comparing pairs of observations at the more sensitive parts of the curve; as, for instance, at 15° and 75° or at 30° and 60°. If the vibration directions of the plate and of the nicols coincide when the reading of the circle is 0°, then the radiomicrometer readings at 15° and 30° must be equal to the readings at 75° and 60° respectively. The following numbers may be quoted in illustration of this point:—

Circle:	15°	30°	60°	75°	105°	120°	135°	150°	165°	195°.
Scale:	2½	6¾	6¾	2½	2½	6¾	8¾	6¾	2½	2½

It will be seen that the corresponding readings on each side of the maxima found at 45° and 135°, or taken at equal inclinations to the minima which occur at 0°, 90°, and 180°, exhibit a satisfactory degree of concordance. Had the readings not accorded as shown in the above observations, the directions of the striae would not be those of symmetry-axes, and the true direction of extinction would be in some other posi-

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tion, and could be deduced from the mean of two positions of equal transmission, or by the method described in the next paragraph.

The intensity, I, of the illumination transmitted by a thin crystal plate placed between crossed nicols is given by the expression

$$I = a^2 \sin^2 2\theta \sin^2 \delta/2,$$

where θ is the angle through which the plate has been turned from the position of extinction. This expression must hold for radiant heat as well as for light, and the scale readings of the radiomicrometer are proportional to the heat transmitted. Suppose, then, that the plate is set in a position making an angle θ with the position of extinction and let the scale reading of the radiomicrometer be x divisions. Next let the plate be turned into the position ϕ through a known angle $\phi - \theta = \psi$, and let the corresponding reading of the radiomicrometer be y. We know then x, y, and the angle ψ, and require to calculate θ or ϕ.

We have $a^2 \sin^2 2\phi \sin^2 \delta/2 = yk$,

and $a^2 \sin^2 2\theta \sin^2 \delta/2 = xk$;

hence $\sin 2\phi / \sin 2\theta = \sqrt{y/x}$.

But $\phi = \theta + \psi$,

and $$\frac{\sin(2\theta + 2\psi)}{\sin 2\theta} = \frac{\sin 2\theta \cos 2\psi + \cos 2\theta \sin 2\psi}{\sin 2\theta},$$

whence $\cos 2\psi + \cot 2\theta \sin 2\psi = \sqrt{y/x}$.

We may make ψ any convenient value we please, such as 15°, 22½°, or 30°.

If $\psi = 15°$ we have

$$\cos 30° + \cot 2\theta \sin 30° = \sqrt{y/x} \text{ or } \cot 2\theta = 2\sqrt{y/x} - \sqrt{3}.$$

If $\psi = 22\frac{1}{2}°$ we have

$$\cos 45° + \cot 2\theta \sin 45° = \sqrt{y/x} \text{ or } \cot 2\theta = \sqrt{2y/x} - 1.$$

If $\psi = 30°$ we have

$$\cos 60° + \cot 2\theta \sin 60° = \sqrt{y/x} \text{ or } \cot 2\theta = 2\sqrt{y/3x} - 1/\sqrt{3}.$$

Thus from two observations the position of extinction may be found. This method has the great advantage that the observations are made at a sensitive part of the curve, and can be so quickly taken that the source of radiation has not time to alter in intensity.

The following example will illustrate the application of this method. The radiomicrometer reading corresponding to a certain position of the crystal plate was 2 scale divisions; on turning the plate through 30° the corresponding reading was 17½ divisions. Substituting, therefore, in the expression $\cot 2\theta = 2\sqrt{y/3x} - 1/\sqrt{3}$ we get

$$\cot 2\theta = 2\sqrt{35/12} - 0.5773 = 2.839, \text{ whence } \theta = 9° 42'.$$

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In order, therefore, to put the plate into the position in which its vibration directions coincide with those of the nicols, it must be turned through 9° 42′ in the opposite sense to its former rotation. After making this adjustment it was found that the directions of vibration in the plate coincided with the directions of the striae.

The experiments described above are to be regarded as of a preliminary character only and leave many interesting points unsettled. Thus the wave-lengths of the radiations transmitted by the antimonite have still to be determined, and the refractive indices of the crystal for these radiations measured. The variations in the absorption for rays vibrating in different directions have also to be studied. It will, moreover, be of interest to discover how far the method is applicable to other substances opaque to light. I hope shortly to be able to extend the investigation in these directions, and to improve materially the delicacy of the method by substituting for lime-light either sunlight or the electric arc.

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1. *Anatase in the Trias of the Midlands of England.* 2. *A peculiar occurrence of Magnetite in the Upper Bunter Sands.*

By John B. Scrivenor, M.A., F.G.S.

Of H.M. Geological Survey.

[Read March 24, 1903.]

1. *Anatase in the Trias of the Midlands of England.*

THE mode of occurrence and origin of the various forms of titanium dioxide as rock constituents have received attention at the hands of many petrologists, both on the continent and in our own country. Among the works of the former dealing with this subject, Thürach's exhaustive treatise[1] on microscopic rock-forming rutile, anatase, and brookite, is undoubtedly the most important: in England, Mr. Maynard Hutchings has described in great detail the occurrence of rutile and anatase both as constituents of clays and slates[2], and as a product of contact metamorphism in the Lower Coniston Flags[3] in the neighbourhood of the Shap granite; Mr. J. J. H. Teall has also described rutile needles and anatase crystals from clays of various ages[4], and anatase from the Cleveland iron-ore[5]; Mr. Allan Dick[6] has mentioned the occurrence of rutile in the Bagshot Sands; and Mr. H. H. Thomas[7] has lately described these minerals from the Budleigh Salterton Pebble-bed of Devonshire.

I have been for some time engaged in examining the mineral constitution of the Triassic sandstones of the Midlands, and have found that of the heavier minerals, that is, those exceeding a specific gravity of 2·8, anatase, both by reason of its abundance and its mode of occurrence, is the most interesting, so much so that although Thürach has already

[1] 'Über das Vorkommen mikroskopischer Zirkone und Titan-Mineralien in den Gesteinen.' Verh. physik.-medic. Ges. Würzburg, 1884, N. F. vol. xviii, No. 10, pp. 1–82.

[2] Geol. Mag., 1890, p. 264.

[3] Quart. Journ. Geol. Soc., 1891, vol. xlvii, p. 318; Geol. Mag., 1891, pp. 459, 528.

[4] Min. Mag., 1887, vol. vii, p. 201.

[5] 'British Petrography,' 1888, pl. 44, fig. 6.

[6] Nature, 1887, vol. xxvi, p. 91.

[7] Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 620.

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called attention to the widespread distribution of this mineral, and has expressed his opinion as to its origin in various rocks, it has been thought worthy of a brief description.

Of a large number of sandstones, few failed to yield more or less anatase; and even where it was not found after a single separation there is no reason to doubt that, judging by the similarity of the associated minerals, a more protracted search would have resulted in success. Although nearly always present, it was found, however, that the ratio of the anatase to the other minerals in the heavy residues was always greater in specimens from the Keuper than in those from the Bunter. The following have been selected as affording the best material for the study of this mineral:—Keuper sandstone from Sutton Coldfield, Storeton in Cheshire, and Weston, also in Cheshire; sandstone from the Bunter Pebble-bed at Dale Abbey, near Derby, and Bunter sandstone from Kingswinford, near Stourbridge.

The anatase crystals vary considerably in size. The smallest that have been measured are 0·025 mm. in greatest diameter; the majority average 0·06 mm.; while a few, especially those with the octahedral faces well developed, reach 0·17 mm. As far as can be ascertained the individuals are composed entirely of the forms {111} and {001}, the extent of development of the latter determining the pyramidal or tabular habit of the crystal. Perfect pyramids, however, with the basal plane completely suppressed, have not been seen. The crystals are generally colourless; but some exceptions have been seen in the specimens from Dale Abbey, where a violet-brown and a yellow crystal were found. Similarly, the crystals are generally perfectly clear, a feature which is partially masked in those with a pronounced pyramidal habit by the strong total reflection; but some, especially among the larger tabular crystals, are encrusted with a granular substance which is white by reflected light. In convergent light, all the crystals were found to be abnormally biaxial, the uniaxial cross opening slightly into hyperbolae on rotation.

Detached crystals occur in these sandstones, but it was noticed that these are very rarely perfect, some flaw being nearly always evident. On the other hand, clusters of minute crystals are frequently met with, and also larger crystals, with a perfectly sharp outline, projecting from the surface of grains of a white substance, sometimes tinged with yellow, red, or brown, which there is every reason to suppose is leucoxene. In support of this view, which it is impossible to prove by chemical methods in the presence of a known titaniferous mineral, it may be mentioned that the nucleus of these white masses has often been

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found to be an opaque black mineral, similar to the cores of ilmenite in masses of leucoxene in igneous rocks. The cleavages parallel to (111) and (001) are rarely evident.

If, like the minerals with which it occurs, namely, zircon, rutile, tourmaline, staurolite, &c., the anatase is of detrital origin, there are two difficulties to be accounted for. First, how is it that the cleavages, which are described as perfect, are not better developed? and again, how is it that the crystals, which are softer than rutile, zircon, or tourmaline, present so sharp an outline, while the last-named minerals are, with few exceptions, distinctly worn? For the sake of comparison, a specimen of anatase from the altered Lower Coniston Flags was examined, with the result that there appeared to be no possibility of the crystals in the sandstones having been derived from such a source, the disparity of size (those in the altered flags being very minute) and the prevalence of the pyramidal habit being fatal objections; nor is there known to be any source within reasonable distance where larger crystals could be derived, such as those mentioned by Thürach as occurring in the granite of Striegau.

That these anatase crystals in the sandstone had been formed after the deposition of the sand, suggested itself early in these investigations; but when undoubted anatase crystals were found completely enclosed in quartz this view had for the time to be abandoned, and for some time no way out of the difficulty was forthcoming. However, the solution presented itself in the Keuper sandstone from Weston, where a detached crystal of anatase was found with a beautifully doubly-terminated quartz crystal growing on it, measuring not more than 0·07 mm. That this delicate quartz crystal had been formed after the deposition of the sand cannot be doubted: if it had been transported by wind or by water, it could not have failed to have become detached from the anatase. Therefore, although one could believe that some, at least, of the anatase came from a distance, if a reasonable source could be pointed out, a sufficient explanation for these quartz-enveloped clusters is that they have become surrounded by a deposition of secondary silica.

When one considers the purely secondary nature of rock-making anatase, that it never is known to occur in fresh igneous rocks, and how abundant and bewildering are the changes experienced by the titaniferous minerals among themselves, in addition to the above considerations of perfection of outline, rarity of cleavage traces, and the absence of any known available source if of detrital origin, the conclusion cannot be resisted that these anatase crystals have been formed, after the deposition

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of the sandstone, from leucoxene, which in turn has been derived from other titaniferous minerals, chiefly ilmenite.

There is another possible source of the anatase. Both my friend Mr. Thomas and myself, while working on the Triassic sandstones, were struck by the great scarcity of sphene, which from its widespread occurrence in igneous rocks, might be expected to be abundant. That this may be accounted for by supposing that some of the anatase has been derived from this mineral, either with or without the formation of leucoxene as an intermediary stage, is very probable, seeing that Diller has described anatase after sphene in amphibole-granite and in 'Schalstein[1].'

In these Triassic sandstones, then, we have, first, leucoxene after ilmenite, then anatase after leucoxene, and lastly secondary quartz deposited on the anatase. Why the leucoxene should afford anatase instead of sphene, an alteration common in other rocks, cannot be explained, seeing that the conditions under which the change took place cannot have been far removed from those of ordinary weathering. Were we dealing with contact metamorphism the problem would be comparatively simple; indeed in the case of the re-crystallization of rutile as anatase, described by Mr. Maynard Hutchings[2], and as brookite, described by Beck in the Silurian clays of Saxony[3], the experiments of Hautefeuille can be profitably appealed to; but in this case, where the conditions cannot have been such as Hautefeuille demanded for the artificial formation of rutile, or even those under which the experiments of Daubrée and Deville were conducted, we must accept the phenomenon as an instance of the unaccountable vagaries of titaniferous minerals, whose only conception of order seems to be a tendency towards the form rutile.

In conclusion, I must record my indebtedness to those who have offered me their assistance, especially to Mr. Allan Dick, and to Mr. Maynard Hutchings, who has placed at my disposal his preparations described in the 'Quarterly Journal of the Geological Society' and in the 'Geological Magazine.'

2. *A peculiar occurrence of Magnetite in the Upper Bunter Sands.*

The specimen of Upper Bunter Sands, in which this magnetite occurs, was collected at Hinksford (Staffordshire), near Stourbridge. It is a white, very loosely coherent sand of medium grain; and contains,

[1] Neues Jahrb. Min., 1888, vol. i, pp. 187, 189.
[2] Geol. Mag., 1891, p. 459.
[3] Min. petr. Mitt. (Tschermak), 1898, vol. xiii, p. 290.

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as was found by separating the constituents in mercury-potassium iodide, turbid orthoclase, microcline, fragments of the micro-crystalline ground-mass of acid lavas or intrusive rocks, quartz, staurolite, tourmaline, garnet, zircon, rutile, muscovite, a little haematite, and abundant magnetite.

The grains of magnetite are very minute, averaging 0·067 mm., but nevertheless they present, with very few exceptions, a perfect crystal outline, that of a simple cube, or, in a few rare cases, that of a regular octahedron. That the mineral is magnetite can be demonstrated both by its behaviour with reagents and by the possibility of separating it from the other grains by a weak magnet. By strong reflected light the dull black surface is in some cases seen to be traversed by a single set of striae parallel to the cubic edge; while on others a red colour can be discerned at the corners of the cubes, which suggests an admixture of a small amount of haematite.

There are two possible explanations of this occurrence. It may, for the sake of argument, be assumed that the grains of the rock were formerly cemented by chalybite, which by oxidization became converted into magnetite, having a form similar to that of the minute cubes described by Sjögren from the Mossgrufva, Nordmark[1]. Apart from the difference of the mode of occurrence, there is, however, an important distinction between the Mossgrufva crystals and those under discussion. The former have their cube faces crossed by a double set of striae at right angles to one another and parallel to the edges, whereas the Hinksford crystals only show one set, which instantly recalls the hemihedral striae of pyrites. This apparently hemihedral striation suggests the second, and I believe the more probable view, namely that the magnetite is pseudomorphous after pyrites, a replacement of which only one record[2], and that a doubtful one[3], can be found in the British Isles, that given in Hall's 'Mineralogist's Directory,' the locality being Tarbet in Argyllshire.

[1] Hj. Sjögren, 'Contributions to Swedish Mineralogy.' Bull. Geol. Inst. Univ. Upsala, 1895, vol. ii, p. 68.

[2] T. M. Hall, 'Mineralogist's Directory,' 1868, p. 132.

[3] H. A. Miers, Min. Mag., 1897, vol. xi, p. 277.

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Bakerite (a new borosilicate of calcium) and Howlite from California.

By W. B. Giles, F.I.C.

[Read March 24, 1903.]

THE new mineral to be described occurs as veins and as nodules of considerable size in the mines of the Borax Consolidated Company, Limited, situated in the Mohave Desert, sixteen miles north-east of Daggett in San Bernardino County, California. The white, amorphous[1] masses resemble in appearance unglazed porcelain or fine white marble. Sometimes the mineral has a faint tinge of a sea-green colour. Its hardness is about 4½, and specific gravity 2·78. Up to the present time no specimens showing any signs of crystallization have been noticed. In external appearance the mineral shows a striking resemblance to the pandermite of Sultan Tchair in Asia Minor, and it may be here noted that this amorphous variety of calcium borate occurs also in the Californian mines.

A fragment of the mineral when heated on platinum wire before the blowpipe imparts to the flame a greenish colour and yields a white, perfectly transparent bead. When free from the external coating or matrix of calcite, the mineral is readily soluble in warm dilute hydrochloric acid without effervescence, and on evaporating the solution the silica gelatinizes. Analyses of two specimens from different mines yielded the following results:—

	White.	Faint greenish.
B_2O_3	27·74 ...	26·85
CaO	34·88 ...	35·22
SiO_2	28·45 ...	28·05
H_2O	8·30 ...	8·66
Al_2O_3, Fe_2O_3 ...	0·63 ...	1·22
	100·00	100·00

[1] Specimens of 'bakerite' presented by Mr. Giles to the British Museum appear to be perfectly homogeneous, except in one piece, which is intermixed with a little calcite. The microscopical examination of several fragments crushed in oil and of a thin section showed the material to have an extremely minute spherulitic structure and to be feebly birefringent. There was nothing suggestive of a mixture of minerals. On the other hand, the specific gravity of several small fragments from two specimens

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The water was estimated by calcining with materials, such as monosodic borate, which prevent any slight simultaneous loss of boric acid: the boric acid by the Ebelmen-Rose-Gooch method (distillation with methyl alcohol), but somewhat modified to make it more practicable than the Gooch process.

These analytical results give the formula:—

$$8CaO . 5B_2O_3 . 6SiO_2 . 6H_2O.$$

The name bakerite is proposed in honour of Mr. R. C. Baker, of Nutfield, Surrey, one of the managing directors of the Company, and by whom the mineral was discovered.

The several borosilicates of calcium hitherto known are:—

Danburite, $CaO . B_2O_3 . 2SiO_2$.
Datolite, $2CaO . B_2O_3 . 2SiO_2 . H_2O$.
Howlite, $4CaO . 5B_2O_3 . 2SiO_2 . 5H_2O$.

For purposes of comparison, the calculated percentage compositions of these, together with that of bakerite, are given below.

	Danburite.	Datolite.	Howlite.	Bakerite.
B_2O_3	28·4	21·8	44·6	27·7
CaO	22·8	35·0	28·6	35·4
SiO_2	48·8	37·6	15·3	28·4
H_2O	—	5·6	11·5	8·5

Howlite.

This mineral, previously recorded only from Nova Scotia, has been considered to be of rare occurrence. It occurs, however, in immense quantities in the Californian borax mines mentioned above, and has been used commercially in the manufacture of borax and boric acid. One large nodule, or rather boulder, noticed by the author when he visited the mines, weighed between two and three hundredweight, and was snow-white, and almost pure. The mineral is found in many forms, sometimes in large masses of fine small scaly crystals soft enough to be crushed in the hand, and sometimes massive in hard rock-like and amorphous masses, and also in intermediate forms. In these mines howlite frequently occurs associated with natroborocalcite or 'cotton-

(differing somewhat in compactness and hardness) varied between about 2·7 and 2·93 (as determined in methylene iodide with indicators of calcite and aragonite).—L. J. Spencer.

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ball,' and with colemanite. In the exceedingly dry air of these desolate regions the soft crystalline mineral loses some of its water.

Many analyses made by the author on various specimens agree exactly with the composition and formula given above.

Analyses of Californian Howlite.

	Pure white mineral in soft scale-like crystals.	Hard rock-like white masses, not crystalline.
B_2O_3	44·88 ...	43·78
CaO	28·45 ...	28·44
SiO_2	15·50 ...	15·33
H_2O	11·58 ...	11·39
Na_2O, MgO ...	0·09 ...	1·06
	100·00	100·00

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Notes on the Wollastonite rock-mass, and its associated minerals, of the Santa Fé Mine, State of Chiapas, Mexico.

By Henry F. Collins, A.R.S.M.

[Read June 9, 1908.]

THE geological features of the immediate neighbourhood of the Santa Fé Mine, which is situated about nine leagues nearly due east of the departmental town of Pichucalco, have been partially described by the author in a paper[1] recently read before the Institution of Mining and Metallurgy. The key to the position, from the point of view alike of mineralogical and of economic interest, is found in a dome-shaped mass of wollastonite in a nearly pure condition, the horizontal section of which, at the lowest level where it has been sufficiently explored to determine its shape, takes the form of an irregular ellipse about 400 yards long by 160 yards wide. With the exception of the ore-bodies, which are developed on the outskirts of this mass and close to the contacts with other rocks, the whole mass is of nearly uniform composition, consisting of the mineral wollastonite in a nearly pure condition and very coarsely crystallized. Towards the outskirts of the mass the pure wollastonite contains a small proportion of garnet (andradite), and passes, usually by insensible gradations, into the payable ore-bodies. These are irregular in form and distribution, and, while still consisting of wollastonite as the principal gangue mineral, contain also small proportions of garnet, quartz, calcite, semi-opal, and other non-metallic minerals; while the principal valuable metallic minerals, bornite and chalcopyrite, are accompanied by small quantities of galena, pyrites, fahlerz, enargite, &c.

Except near the edge of the mass, the massive wollastonite is not crystallized confusedly from a number of centres, but shows a parallel orientation over distances of many feet. The mineral has two well-developed cleavages approximately at right angles to each other, and the mass breaks readily into fissile rectangular blocks; the resulting structure resembles that of satin-spar, the parallel crystalline fibres often, however, reaching three or four feet in length. In colour the wollastonite is—except where stained by traces of iron and other minerals—

[1] 'Concentration and smelting, as applied to the treatment of low grade gold-copper ores at Santa Fé (Mexico).'

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pure white and translucent; its lustre varies from vitreous to satiny; its hardness is 5, and its specific gravity (average of several determinations) is 2·88.

Origin of the Wollastonite mass. Although a mineral of somewhat wide distribution, wollastonite has hitherto never been known to form the sole constituent of an important rock-mass, but is generally found associated with garnet, epidote, idocrase, and other well-known products of metamorphic action upon impure limestones near their contacts with igneous rocks. In the paper referred to, however, the author adduces arguments to show that this particular mass of wollastonite is not a product of metamorphism *in situ*, but that it has been intruded in a perfectly plastic condition, and that the ore-bodies have been separated from it by magmatic segregation. The principal arguments in favour of such a supposition may be recapitulated as follows:—

1. The wollastonite is absolutely isolated from the limestone rocks of the district, the nearest outcrop of which is situated at a distance of one mile from the outskirts of the mass.

2. It is completely surrounded on all sides by granite, felsite, diabase, and other igneous rocks. The felsite and diabase are in close association with the wollastonite, and the granite surrounds them all at a short distance.

3. The mass is hump- or dome-shaped, its outer surface dipping away from the centre in all directions. The top of the dome only just reaches the present surface, and at the time of its intrusion probably fell short of reaching the then existing surface by several thousand feet. No very long lapse of time, geologically speaking, is required for the denudation of a few thousand feet of rock in a mountainous tropical region possessing an average rainfall of about 200 inches per annum.

4. At a depth of 200 feet below its highest point, mining operations have fairly well mapped out the extent and form of the mass, and have proved it to cover an area about 400 yards long by 160 yards wide, while at an horizon 100 feet deeper its unbroken character has been already proved over an area at least 200 yards long by 80 yards wide. Near the upper surface and outer edge of this mass the pure wollastonite is contaminated with other minerals, is much split up, and includes fragments of the surrounding rocks; it is near this outer contact that ore-bodies have been developed, and that evidences of fissuring and of secondary alteration are met with. Near its outer fringe, moreover, the wollastonite has been penetrated by trap dykes of an obviously later origin. Taking, however, only the central unaltered and undisturbed

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core of the mass, which certainly contains over two million cubic yards of material above the deepest level at which it has been yet opened up, while it presents every indication of continuing unaltered down to unknown depths, it is noteworthy that in the thorough exploration of this very large mass of rock by a network of drivages in all directions, no variation in composition is anywhere observable between different parts of the mass nor in the relative proportions of lime and silica present, no vestige of a transition from limestone to wollastonite, and no indication of a variation in the crystalline structure, which is perfectly developed and uniform throughout.

It is admittedly a unique occurrence for so large a mass of eruptive rock to be composed of practically a single mineral species, but it seems difficult to conceive that so large a mass of limestone could be gradually metamorphosed by siliceous solutions or vapours in such a way as to produce a pure anhydrous silicate of lime of absolutely definite composition and of uniformly macro-crystalline structure throughout. In portions of the rock-mass which are traversed by master-joints the crystalline fibres usually run perpendicularly to these joints, and are often strictly parallel to each other over a width of as much as fifty feet, and absolutely continuous for four to six feet from joint to joint. After long and careful study of the conditions on the spot the author is convinced that these and all the other observed facts can only be explained on the supposition of the eruptive origin of the wollastonite mass.

Crystals of Wollastonite. In cavities and open spaces near the outer edge of the wollastonite intrusion, stout tabular and prismatic crystals of wollastonite are found, varying from half an inch up to nearly a foot long, and the largest of these are almost invariably converted partially or entirely into quartz or semi-opal. The smaller crystals are always found in small cavities, which were almost completely sealed against the passage of solutions, and these have generally remained almost or quite unaltered; but the largest crystals are all found in much larger cavities, which have evidently at a later date been water channels, and most of these are almost entirely converted into silica, sometimes crypto-crystalline, sometimes amorphous. The largest and finest crystal found has been placed in the British Museum; it measures 10¼ inches long by 5½ inches wide. Specimens of the unaltered wollastonite crystals, which are sometimes pink, though generally white, vary from ½ inch long by ⅜ in. wide, up to 2¼ in. by 1¼ in.

It is quite evident that the agency which has effected the transformation of the wollastonite into nearly pure silica is merely that of the

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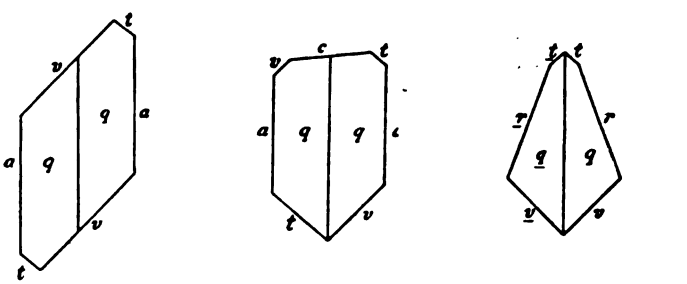
surface waters percolating down through the mass of wollastonite and decomposing the silicate exclusively through the action of their dissolved carbonic acid. In some cases veinlets are found in the wollastonite mass full of secondary calcite or quartz, and more rarely both quartz and calcite are found crystallized side by side in the same veinlet, both evidently derived from the surrounding wollastonite by the agency of the percolating surface waters.

The following crystallographic details, determined on specimens now in the British Museum, have been supplied by Mr. L. J. Spencer:—

The large and somewhat roughly developed crystals of wollastonite from Mexico are elongated in the direction of the axis of symmetry, and the faces in this prismatic zone are deeply striated in the same direction. They are usually attached at one end, only one doubly terminated crystal being observed. There are perfect cleavages parallel to a (100) and c (001), from which fairly good measurements could be obtained, the mean of twenty-one readings being $ac = 84° 37'$. A few crystals are twinned on a (100), giving rise to a small salient or re-entrant angle (measured 10° 44′) between two c cleavages. The forms prominently developed and which could be determined with certainty are[1]:—a {100}, c {001}, v {101}, t {$\bar{1}$01}, r {301}, q {340}; these are shown in the accompanying figures. The hemihedral development of the crystal represented in the second of these figures is not due to twinning, as is the case with another crystal of very similar appearance. The third figure represents a twinned crystal.



Wollastonite crystals from Mexico.
(Orthogonal projections on the plane of symmetry.)

The plane of the optic axes coincides with the plane of symmetry, and the sign of the double refraction is negative. Through a cleavage flake parallel to a there emerges an optic axis outside the field of view (¼ inch objective in oil), and through the c cleavage is seen, towards the edge of the field, the set of rings around the second axis. The acute bisectrix lies in the acute[2] axial angle β, and is inclined at

[1] Letters and indices as in Dana's 'System of Mineralogy,' 6th edit., 1892.

[2] Not in the obtuse axial angle, as incorrectly quoted from Des Cloizeaux by Dana and in Rosenbusch's 'Rock-making Minerals' (2nd German, and 1st–4th English, editions).

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only a few degrees to the normal to $\bar{x}(\bar{1}01)$; through this plane the optic figure is thus seen nearly centrally. The axial angle in cedar oil was approximately measured with a stage-goniometer as $2H_a = 40°$.

In attempting to cut sections parallel to a plane of symmetry, the material readily broke up into fine fibres perpendicular to this plane. This almost fibrous structure of the crystals is perhaps due, not so much to the perfect cleavages, as to the presence of numerous, very fine, tubular cavities. These cavities are arranged parallel to the axis of symmetry, and are much elongated in this direction: under a high magnification some were seen to contain liquid and a bubble of gas.

Wollastonite with Bornite. In the ore-bodies near the edges of the mass, the essentially parallel development of the crystalline fibres of the wollastonite gives place to a confused network of small interpenetrating crystals, between which small crystals of bornite, chalcopyrite, and garnet have developed. This forms the ordinary concentrating ore worked in the mine, and it clearly exhibits the way in which the metallic and other impurities in the mass were eliminated during its cooling, so as to leave in the central portion nothing but pure silicate of lime. In other parts of the ore-bodies the impurities have been concentrated to a much higher degree, so as to produce masses of garnet mixed with copper minerals which are rich enough to be treated by direct smelting to regulus.

It may be remarked that the whole of the copper minerals carry precious metals, each ton of fine copper in the product of the mine containing on an average 9 ozs. gold and 160 ozs. silver.

Chalcedony containing Bornite. One small mass of this material was found forming the filling of a cavity in the wollastonite. It appears as a solidified jelly of grey semi-transparent chalcedony with minute spots of bornite.

Opal. In some places close to the outskirts of the wollastonite mass, and along lines of fissuring which run in a curved direction following the exterior of the mass, the processes of solution of lime and re-deposition of silica have gone so far as to leave nothing but a mass of semi-opal, more or less stained by iron oxide and copper carbonate, which occasionally attains a width of two or three feet.

Garnet. Like most of the garnet found all over Mexico associated with contact-zones between porphyries and limestones, this is an aluminous andradite. It is found in rhombic dodecahedral crystals embedded in the wollastonite and in small cavities. In colour it varies from olive-green to resin-yellow and reddish-brown, but crystals of the different colours vary very little in chemical composition, as shown by the following partial analyses:—

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	Green.	Brown.	All colours.
Silica	36·10	36·48	36·35
Alumina	—	—	12·37
Ferric oxide ...	19·30	19·50	19·43
Lime	—	—	33·33
Magnesia ...	—	—	0·40
			101·88

The average of a number of determinations of the specific gravity gave 3·89, which is higher than one would expect from the chemical composition.

Auriferous Linnaeite. In some of the massive bornite, as well as in some of the mixed rock from the ore-bodies carrying copper minerals, but always in very close association with the bornite, grains of a brittle, steel-grey mineral are sometimes found, and these on analysis turned out to be linnaeite (the nickeliferous variety, siegenite). A number of grains of the mineral were carefully picked out under the lens so as to be free from intermingled grains of bornite, and a portion of the picked mineral submitted to analysis, with the following results:—

Sulphur	44·31
Cobalt	29·64
Nickel	17·15
Iron	3·32
Copper	5·32
Gold	0·53 (= 173 ozs. per ton)
Silver	0·13 (= 42 „)
Insoluble residue (quartz)	0·43
	100·83

Arsenic, antimony, bismuth, and tellurium were searched for but not found. The above figures agree closely with the formula

$$(Ni,Cu,Fe,Co)S.CoS_2.$$

The peculiarity of this mineral is in its gold and silver contents. It is often found associated with free gold, and the small specimens pulverized for analysis left, upon a screen of 120 meshes to the inch, metallic gold in amount equivalent to over 200 ozs. per ton. The author believes, however, that a portion of both the gold and silver contents occur in a chemically combined condition, replacing the other metals, since they cannot be wholly separated from the mineral by amalgamation[1], and suggests that they exist as sulphides replacing cobalt.

[1] Details of the experiments are given in Trans. Inst. Mining and Metallurgy, 1900, vol. viii, p. 804.

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Enargite. This mineral is met with in parts of the ore-bodies near the present surface, where abundant evidence of secondary enrichment is forthcoming in connexion with extensive deposition of calcite and of massive bornite. It forms small, brilliant black crystals bounded by the macropinacoid a {100}, prism m {110}, and basal pinacoid c {001}, all of which are about equally developed. The crystals are quite short in the direction of the vertical crystallographic axis c, and are not, as is usually the case in enargite, attached at one end of this axis. They are frequently arranged in stellate twinned groups of three individuals intercrossing at approximately 60°. The crystals sometimes occur on quartz in cavities, but more generally investing masses of bornite.

Interlamination of Bornite and Galena. This peculiar occurrence, which the author believes to be unique, is very rare, only two or three specimens having been met with. The first specimen found, which was also by far the largest, was met with as a nodule in a mass of soft, decomposed, ochreous material containing garnet and quartz, which formed the outcrop of one of the ore-bodies occurring near a contact of wollastonite with felsite-porphyry. Diligent search was subsequently made for this mineral in unaltered portions of the ore-body immediately below, and was rewarded by finding several small nodules in pure unaltered wollastonite, the largest of which is about the size of a hazel-nut. The material is very rich in the precious metals, a specimen assayed containing at the rate of 14 ozs. gold and 108 ozs. silver per ton.

This peculiar interlamination reminds one of graphic granite, or of the inter-crystallization of some of the felspars. Most of all does it resemble the structure of eutectic alloys as exhibited by micro-photographs of polished surfaces under a magnifying power of several hundred diameters; in fact, except as to scale, the form and arrangement of the interlaminations are absolutely identical.

Idocrase in Crystalline Limestone.

Near the top of a limestone peak, about one and a half miles south of Santa Fé, very difficult of access and covered by dense bush, is a small outcrop of a coarsely crystallized rock, which consists largely of crystals of idocrase set in a matrix of calcite. The crystals of idocrase are stout prisms from $\frac{3}{4}$ to $1\frac{1}{4}$ inch in length, of a dark yellowish-green to leek-green colour, and almost invariably coated with scales of talc. They show the forms m {110} and p {111}, with subordinate a {100}.

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A (third) list of new mineral names[1].

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

Alkali-garnet. W. C. Brögger and H. Bäckström, Zeits. Kryst. Min., 1890, vol. xviii, p. 215 (Alkaligranate, *pl.*). A general term for members of the sodalite group; these being closely related crystallographically and chemically to the true garnets. (Cf. the artificial lagoriolite = natrongranat of J. Morozewicz, 1898.)

Amianthinite. R. Kirwan, Elements of Mineralogy, 2nd edit., 1794, vol. i, p. 164. Asbestiform actinolite.

Ammonium-analcite, Ammonium-leucite, Ammonium-natrolite, Ammonium-stilbite, &c. F. W. Clarke and G. Steiger, Amer. Journ. Sci., 1900, ser. 4, vol. ix, pp. 117, 345; ibid., 1902, vol. xiii, p. 27; Bull. U. S. Geol. Survey, 1902, No. 207. Artificial derivatives of analcite, &c., with ammonium in place of sodium, potassium, or calcium.

Anapaite. A. Sachs, Sitz.-ber. Akad. Wiss. Berlin, 1902, p. 18; Zeits. angew. Chem., 1902, vol. xv, p. 111; 80er Jahres-Ber. Schlesisch. Ges., for 1902, 1903, Abt. II, Sect. *a*, p. 3 (Anapait). J. Loczka, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 488. Pale green, glassy crystals on limonite, from Anapa, Black Sea. Anorthic. $FeCa_2(PO_4)_2 . 4H_2O$. Differs from messelite only in containing a little more water. *See* tamanite.

Anemolite. J. Barnes and W. F. Holroyd, Trans. Manchester Geol. Soc., 1896, vol. xxiv, p. 232 (anemolites). A curved and upturned form of stalactite of calcium carbonate from the Derbyshire limestone caves. Named from ἄνεμος, wind, and λίθος, stone, because of the

[1] The two preceding lists of this series will be found at the ends of vols. xi and xii of this Magazine. A few earlier names, omitted from Dana's 'System of Mineralogy' (6th edit., 1892) and Chester's 'Dictionary of the Names of Minerals' (1896), are included. Certain less accessible names, more especially in Russian literature, have been very kindly supplied by Professor W. Vernadsky, of Moscow. The original spelling of a name, as printed on the page cited, is added in parentheses whenever it differs from the spelling adopted in this list; the case-endings of Russian names have, however, been altered to the nominative.

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influence of varying currents of air in determining the direction which the stalactites take.

Ankylite. G. Flink, Meddelelser om Grönland, 1901, Hefte xxiv, plate III. [The reprint of Flink's paper is dated 1899, but was not issued till 1900; Hefte xxiv is dated 1901.] The same as ancylite.

Antimon-luzonite. S. Stevanović, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 235 (Antimon-Luzonit, Stibio-Luzonit). A massive mineral, with a reddish colour and absence of cleavage, from Peru. In composition, $Cu_3(As,Sb)S_4$, it is intermediate between luzonite and famatinite. It is identical with the 'famatinite' from Chile analysed by A. Frenzel in 1875.

Arsensulfurite. F. Rinne, Centralblatt Min., 1902, p. 499 (Arsensulfurit). Amorphous sulphur containing much arsenic (29·22 per cent.). A volcanic sublimation from Java.

Artinite. L. Brugnatelli, Rend. Ist. Lombardo, 1902, ser. 2, vol. xxxv, p. 874; Centralblatt Min., 1903, p. 144. A loose aggregate of snow-white scales which are composed of minute prismatic crystals. The optical characters agree with orthorhombic symmetry. In composition, $MgCO_3 . Mg(OH)_2 . 3H_2O$, near to hydrogiobertite, which, however, is shown to be a mixture of at least two minerals. In peridotite from the Val Lanterna, Val Tellina. Named after Prof. Ettore Artini, of Milan.

Badenite. P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, p. 29; Anal. Acad. Române, Bukarest, 1900, vol. xxii; (abstract, this vol., p. 207). A massive steel-grey mineral which appears to be smaltite (or safflorite) with part of the arsenic replaced by bismuth (4·76 per cent.); $(Co,Ni,Fe)_3(As,Bi)_2$. From Badeni, Roumania.

Bakerite. W. B. Giles, Min. Mag., 1903, vol. xiii, p. 353. A massive borosilicate of calcium, $8CaO . 5B_2O_3 . 6SiO_2 . 6H_2O$, from the borax mines of California. Named after Mr. R. C. Baker, of Nutfield (Surrey), by whom the mineral was found.

Baumhauerite. R. H. Solly, Min. Mag., 1902, vol. xiii, p. 151; 1903, vol. xiii, p. 339; Zeits. Kryst. Min., 1903, vol. xxxvii, p. 321. Crystals resembling in general appearance the several other sulpharsenites of lead from the Binnenthal dolomite. Monoclinic. $4PbS . 3As_2S_3$. Named after Professor Heinrich Baumhauer, of Freiburg, Switzerland.

Bavenite. E. Artini, Rend. Accad. Lincei, Roma, 1901, ser. 5,

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vol. x, sem. 2, p. 139. Radiating tufts of white needles in the drusy cavities of the Baveno granite. Monoclinic, but twinned to simulate orthorhombic symmetry. $3CaO . Al_2O_3 . 6SiO_2 . H_2O$. Approaches pilinite in composition.

Bleimalachit. S. F. Glinka, Centralblatt Min., 1901, p. 281. Acicular crystals of orthorhombic habit, but monoclinic and twinned. $2CuCO_3 . Cu(OH)_2 . PbCO_3$. Altai Mountains. *See* plumbomalachite.

Bleizinkchrysolith. P. P. Heberdey, Zeits. Kryst. Min., 1892, vol. xxi, p. 56. An artificial product (from a crystallized slag) with the composition $PbZnSiO_4$ and isomorphous with chrysolite.

Bodenzeolith. *See* geolyte.

Boothite. W. T. Schaller, Bull. Dep. Geol. Univ. California, 1903, vol. iii, p. 207. A copper sulphate with $7H_2O$, instead of $5H_2O$ as in chalcanthite; $CuSO_4 . 7H_2O$. Monoclinic, and isomorphous with melanterite. Occurs with other sulphates as an alteration product of chalcopyrite in the Alma mine, Leona Heights, Alameda Co., California. Named after Mr. Edward Booth, of the University of California.

Bourgeoisite. R. Breñosa, Anal. Soc. Española Hist. Nat., 1885, vol. xiv, p. 129 (Bourgeoisita). Described as a tetragonal modification of calcium silicate dimorphous with wollastonite. In a devitrified glass of doubtful origin. Named after Dr. L. Bourgeois, of Paris.

Breadalbanite. (Catalogue of the Mineral Collections in the Museum of Practical Geology. By W. W. Smith and others. London, 1864, p. 180.) A variety of hornblende from Perthshire, Scotland. T. Egleston (Catalogue of Minerals and Synonyms, Washington, 1887, Bull. U. S. National Mus., 1889, No. 33) gives breadalbaneite (p. 13) and breadalbanite (p. 33).

Brostenite. P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, p. 53; Anal. Acad. Române, Bukarest, 1900, vol. xxii; (abstract, this vol., p. 207). Black friable masses occurring as an alteration product of rhodochrosite, near Brosteni, Roumania. The results of three analyses show it to be a hydrated manganite of iron and manganese near chalcophanite, but of variable composition.

Brunsvigite. J. Fromme, Min. petr. Mitt. (Tschermak), 1902, vol. xxi, p. 171 (Brunsvigit). A chloritic mineral, near metachlorite, occurring as fine scaly masses in the gabbro of Radauthal, Harz (Brunswick).

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Ceruleite. H. Dufet, Bull. Soc. franç. Min., 1900, vol. xxiii, p. 147 (céruléite). Turquoise-blue, clayey masses. Under the microscope it is seen to be minutely crystalline. $CuO.2Al_2O_3.As_2O_5.8H_2O$. Huanaco, Chile. Named from the Latin, *caeruleus*, sky-blue.

Chalmersite. E. Hussak, Centralblatt Min., 1902, p. 69 (Chalmersit). Brilliant, bronze-yellow, acicular crystals very similar to copper-glance in habit, twinning, and angles; they are magnetic like pyrrhotite. Orthorhombic. $CuFe_3S_4 = Cu_2S.Fe_6S_7$ (but only 0·016 gram of material analysed). Associated with pyrrhotite, &c. at the Morro Velho gold-mine, Minas Geraes, Brazil. Named after Mr. G. Chalmers, the superintendent of the mine.

Chocolate-stone. *See* lacroisite.

Chromocyclite. C. Klein, Jahrb. Min., 1892, vol. ii, pp. 176, 220 (Chromocyclit); C. Hintze, Handb. d. Min., 1897, vol. ii, p. 1783 (Chromocyklit). Apophyllite which shows coloured interference rings in convergent polarized light, as distinct from the black and white rings of the leucocyclite variety.

Ciempozuelite. A. de Areitio y Larrinaga, Anal. Soc. Española Hist. Nat., 1873, vol. ii, p. 393 (Ciempozuelita). $8Na_2SO_4.CaSO_4$. From the salt mines at Ciempozuelos, Madrid. [Possibly a mixture of glauberite ($Na_2SO_4.CaSO_4$) and thenardite (Na_2SO_4), both of which occur at this locality.]

Clinoaugite. *See* orthoaugite.

Clinopyroxene. *See* orthoaugite.

Coolgardite. A. Carnot, Compt. rend. Acad. Sci., Paris, 1901, vol. cxxxii, p. 1300; Bull. Soc. franç. Min., 1901, vol. xxiv, p. 360; Ann. des Mines, sér. 9, vol. xix, p. 533. Described as a sesquitelluride of gold, silver, and mercury from Kalgoorlie, East Coolgardie gold-field, Western Australia. Proved to be a mixture of coloradoite (HgTe), and the gold and silver tellurides, calaverite, sylvanite, and petzite (L. J. Spencer, Min. Mag., 1903, vol. xiii, p. 268).

Ctypeite. Bull. Soc. franç. Min., 1901, vol. xxiv, p. 456, abstracts (ctypéite). The same as ktypeite (A. Lacroix, 1898).

Cumengite. P. Groth, Tab. Uebers. d. Min., 1898, 4th edit., p. 55 (Cumengit); E. S. Dana, 1st appendix to the 6th edit. of Dana's System of Mineralogy, 1899, p. 21. The same as the cumengeite of Mallard (1893, named after Mr. E. Cumenge); not the cumengite of Kenngott (1853).

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Diestit. Zeits. Kryst. Min., 1901, vol. xxxiv, p. 720; Chem. Central-Blatt, 1901, Jahrg. 72, vol. ii, p. 828. The same as vandiestite (q. v.).

Discachatae. M. F. Heddle, Trans. Geol. Soc. Glasgow, 1900 [1901], vol. xi, pp. 167–9; Heddle, Mineralogy of Scotland, 1901, vol. i, pp. 70–2 (Discachatæ). This and other names (haemachatae, haema-ovoid-agates, oonachatae) are proposed for structural varieties of agate, defined by the enclosure of discoidal or ovoidal patches of cacholong, &c., sometimes of a red colour.

Eglestonite. A. J. Moses, Amer. Journ. Sci., 1903, ser. 4, vol. xvi, p. 253. Cubic oxychloride of mercury, $Hg_6Cl_2O_2$. The brownish-yellow colour of the crystals quickly changes to black on exposure to light. Named after the late Professor Thomas Egleston, of Columbia University, New York. *See* terlinguaite.

Eisencordierit. H. Bücking, Ber. Senckenberg. Naturf. Ges. Frankfurt-am-Main, 1900, p. 15. Cordierite with magnesia largely replaced by ferrous iron, as is the case in the cordierite of the 'vitrified' sandstones altered by contact with basalt in central Germany.

Eisenrömerit. *See* ferrorömerite.

Erzbergite. E. Hatle, Mitth. naturwiss. Ver. Steiermark, 1892, vol. xxviii (Jahrg. 1891), p. 295 (Aragonit-Calcit-Sinterbildungen (Erzbergit)). A calcareous deposit from Erzberg, Eisenerz, Styria, consisting of alternate layers of calcite and aragonite.

Esmeraldaite. A. S. Eakle, Bull. Dep. Geol. Univ. California, 1901, vol. ii, p. 320. Pod-shaped masses of a coal-black colour and bright vitreous lustre; it has a glassy fracture, and in thin splinters transmits yellowish-red light; streak, yellowish-brown. The mean of several analyses gives, after deducting 17 per cent. of impurities, the formula $Fe_2O_3 . 4H_2O$. Found in earthy limonite in Esmeralda Co., Nevada.

Ferropallidite. R. Scharizer, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 547 (Ferropallidit). A white, granular ferrous sulphate, $FeSO_4 . H_2O$, occurring with römerite in Chile. Named from *ferrum*, iron, and *pallidus*, pale.

Ferrorömerite. R. Scharizer, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 546 (Eisenrömerit, Ferrorömerit). A synonym of römerite. *See* zinc-römerite.

Geolyte. E. A. Wülfing, Jahreshefte Ver. vaterl. Naturk. Württemberg, 1900, vol. lvi, p. 85 (Geolyt). To replace the term 'Bodenzeolith'

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used by agricultural chemists for those constituents of soils which are readily soluble and of indefinite mineralogical composition, but have little in common with zeolites. Named from γῆ, earth, and λύειν, to dissolve.

Grandidierite. A. Lacroix, Bull. Soc. franç. Min., 1902, vol. xxv, p. 86. A blue, sapphirine-like mineral in granite from Madagascar. Orthorhombic, with strong pleochroism. Sp. gr. = 2·99. A basic silico-aluminate of iron, magnesium, and calcium with 2 per cent. of alkalies. Named after Mr. Alfred Grandidier, an authority on the geography and natural history of Madagascar.

Hackmanite. L. H. Borgström, Geol. För. Förh. Stockholm, 1901, vol. xxiii, p. 563 (Hackmanit). A member of the sodalite group occurring as rhombic dodecahedral crystals of a pale reddish-violet colour in a rock called tawite from the Tawa valley, Kola peninsula, Lapland. It has the composition of sodalite, $Na_4(AlCl)Al_2(SiO_4)_3$, but contains in addition 6·23 per cent. of $Na_4[Al(NaS)]Al_2(SiO_4)_3$, a compound which Brögger and Bäckström (1890) concluded to be a constituent of the artificial product known as 'white ultramarine.' The sulphur is present as monosulphide, and not as polysulphide as in lazurite. Named after Dr. Victor Hackman, of Helsingfors.

Haemachatae. *See* discachatae.

Haema-ovoid-agates. *See* discachatae.

Hellandite. W. C. Brögger, Nyt Mag. Naturvid. Kristiania, 1903, vol. xli, p. 213 (Hellandit). Monoclinic crystals in the pegmatite-veins near Kragerö, Norway; they are much altered; the freshest contained 7·55 per cent. of water and were optically isotropic (like gadolinite, orthite, &c.). Probable formula: $Ca_2R_2'''(R'''O)_3(SiO_4)_4$, where R''' = Ce,Di,La,Al,Fe,Mn. Related to guarinite. Named after Professor Armund Helland, of Christiania.

Histrixite. W. F. Petterd, Papers and Proc. Roy. Soc. Tasmania for 1900–1, 1902, p. 77; ibid., for 1902, 1903, p. 24; Rep. Secr. Mines, Tasmania, for 1901–2, 1902, p. 294. Radiating groups of orthorhombic crystals, associated with chalcopyrite, bismuthinite, &c., at Ringville, Tasmania. Described as a sulphide of antimony and bismuth with the formula $7Bi_2S_3 . 2Sb_2S_3 . 5CuFeS_2$. [Probably a mixture.] Named histrixite (porcupine-ore) from the Latin, *hystrix* (*histrix*), a porcupine.

Hörnbergite. J. F. Vogl? (— Adam, Tableau Minéralogique, Paris, 1869, p. 42). An arsenate of uranium.

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Huelvite. *See* lacroisite.

Hussakite. E. H. Kraus and J. Reitinger, Zeits. Kryst. Min., 1901, vol. xxxiv, p. 268 (Hussakit); (abstract, this vol., p. 307). E. Hussak and J. Reitinger, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 563. A synonym of xenotime. Named after Dr. Eugen Hussak, of the Geological Survey of São Paulo, Brazil.

Hydrogöthite. P. A. Zemĭatčenskij, Trav. Soc. Nat. St.-Pétersbourg, 1889, vol. xx, Sect. Géol. et Min., p. 208 (*гидрогематитъ*); (abstract, Zeits. Kryst. Min., 1892, vol. xx, p. 185). J. Samojlov, Zeits. Kryst. Min., 1901, vol. xxxv, p. 272. A fibrous (crystalline), cochineal-red hydroxide of iron, $3Fe_2O_3 . 4H_2O$, occurring as veins in limonite in central Russia.

Iodembolite. G. T. Prior and L. J. Spencer, Centralblatt Min., 1902, p. 186 (Jodembolit); Min. Mag., 1902, vol. xiii, p. 176 (iodiferous embolite or iodembolite). To replace the name iodobromite ($2AgCl . 2AgBr . AgI$, which has no existence as a definite compound), and as a general term for minerals of the cerargyrite group (holohedral-cubic silver haloids) containing chlorine, bromine, and iodine, Ag(Cl,Br,I).

Kali-Harmotom. L. Gmelin, Leonhard's Zeits. Min., 1825, vol. i, p. 11. Synonym of phillipsite.

Kalkeisencordierit. H. Bücking, Ber. Senckenberg. Naturf. Ges. Frankfurt-am-Main, 1900, p. 7. Cordierite with lime and ferrous oxide in place of magnesia. In ejected volcanic blocks from the Celebes.

Keweenawite. G. A. Koenig, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 410. A massive, finely-granular mineral, with a pale pinkish-brown colour and metallic lustre, from the Mohawk mine, Keweenaw Co., Michigan. Analyses agree approximately with the formula $(Cu,Ni,Co)_2As$. *See* mohawkite.

Klinoaugit. *See* orthoaugite.

Klino-pyroxen. *See* orthoaugite.

Koenenite. F. Rinne, Centralblatt Min., 1902, p. 493 (Koenenit). A red, scaly mineral with a perfect micaceous cleavage, from the salt deposits of Volpriehausen, Hanover. Rhombohedral, optically uniaxial and positive. $Al_2O_3 . 3MgO . 2MgCl_2 . 6(or\ 8)H_2O$. Named after Professor Adolf von Koenen, of Göttingen.

Kunzite. C. Baskerville, Science, New York, 1903, n. ser., vol. xviii, p. 303. G. F. Kunz, Science, New York, 1903, vol. xviii, p. 280; Amer.

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Journ. Sci., 1903, ser. 4, vol. xvi, p. 264. A lilac-coloured gem-variety of spodumene from California. Named after Dr. George Frederick **Kunz**, of New York.

Lacroisite. H. Lienau, Chemiker-Zeitung, 1903, Jahrg. xxvii, p. 15 (Lacroisit). Torrensite and viellaurite, from manganese mines in the Pyrénées, previously described as new minerals by Lienau (ibid., 1899, Jahrg. xxiii, p. 418), have been shown on microscopical examination by A. Lacroix (Bull. Soc. franç. Min., 1900, vol. xxiii, p. 251) to be mixtures of various manganese minerals (mainly rhodochrosite, tephroite, and rhodonite). Lienau now describes other similar mixtures under the names lacroisite (a mixture of rhodochrosite and rhodonite; named after Professor Alfred Lacroix, of Paris), Schokoladenstein (chocolate-stone), and huelvite (from Huelva, Spain).

Lardite. P. A. Zemlatčenskij, Trav. Soc. Nat. St.-Pétersbourg, 1889, vol. xx, Sect. Géol. et Min., p. 216 (*лардумъ*); (abstract, Zeits. Kryst. Min., 1892, vol. xx, p. 185). Hydrated silica occurring in clay in central Russia; while still moist it is white and slightly transparent, but on drying it becomes opaque. Named from the Latin, *lardum*, lard. The name lardite was used by J. G. Wallerius in 1788 for steatite. *See* ljardit.

Lassallite. G. Friedel, Bull. Soc. franç. Min., 1901, vol. xxiv, p. 6. A substance resembling matted asbestos, which, under the microscope, is seen to consist of birefringent fibres. $3MgO . 2Al_2O_3 . 12SiO_2 . 8H_2O$. France. Named after M. Lassalle, a mine proprietor.

Ledouxite. J. W. Richards, Amer. Journ. Sci., 1901, ser. 4, vol. xi, p. 458; Chem. News, 1901, vol. lxxxiv, p. 29. The copper arsenide $(Cu,Ni,Co)_4As$, analysed by Dr. Ledoux, and previously named mohawkite (q. v.).

Leukosphenite. G. Flink, Meddelelser om Grönland, 1901, Hefte xxiv, plate VII. The same as leucosphenite.

Liveingite. R. H. Solly, Proc. Cambridge Phil. Soc., 1901, vol. xi, p. 239; Min. Mag., 1902, vol. xiii, p. 160 footnote; (abstract, this vol., p. 206). Crystals resembling in general appearance the several other sulpharsenites of lead from the Binnenthal dolomite. Monoclinic. $5PbS . 4As_2S_3$. Named after Professor G. D. Liveing, of Cambridge.

Ljardit. (Neues Jahrb. Min., 1901, vol. ii, –408–, abstracts.) The same as lardite (q. v.).

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Lotrite. G. Munteanu-Murgoci, Bull. Soc. Sci. Bukarest, 1900, vol. ix, p. 596; 1901, vol. ix, p. 783; Inaug.-Diss. München, 1901 (Lotrit). A constituent of an epidote-schist occurring in contact with serpentine in the Lotru valley, southern Carpathians. $3(Ca,Mg)O_2.Al_2O_3.4SiO_2.2H_2O$. Very similar to prehnite, but differs slightly from this in optical characters, as determined under the microscope in rock-sections.

Macrolepidolite. H. Baumhauer, Eclogae geol. Helvetiae, 1903, vol. vii, p. 354. Two varieties of lepidolite, one with a large optic axial angle, and the other with a small angle, are distinguished and called respectively macrolepidolite and microlepidolite (Makrolepidolith and Mikrolepidolith); the two varieties also differ in the character of the etched figures on the cleavage planes.

Malachite de plomb. (Internat. Catal. Sci. Liter., 1903, Mineralogy volume for 1901, p. 108.) *See* plumbomalachite.

Manganosphaerite. K. Busz, Neues Jahrb. Min., 1901, vol. ii, p. 129 (Manganosphärit). Resembles sphaerosiderite in appearance, but has the composition of oligonite ($3FeCO_3.2MnCO_3$), from which it only differs in being not in crystals. In cavities in a basalt-vein at Horhausen, Rhenish Prussia. [The name would suggest either a botryoidal manganese carbonate or a manganiferous sphaerite (hydrated basic aluminium phosphate).]

Melanochalcite. G. A. Koenig, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 404. A pitch-black, amorphous mineral occurring as thin bands in nodules composed of cuprite, malachite, chrysocolla, and quartz at Calumet, near Bisbee, Arizona. A basic silico-carbonate of copper, $Cu_3(Si,C)O_4.Cu(OH)_2$. Named from μέλας, μέλανος, black, and χαλκός, copper.

Mesolitine. J. Apjohn, Journ. Geol. Soc. Dublin, 1844, vol. iii, p. 77. Identical with thomsonite. Named mesolitine because of a supposed relation to mesolite.

Metachalcolite. Bull. Soc. franç. Min., 1902, vol. xxv, p. 372 (abstract of Rinne's paper). Synonym of metakupferuranit (q. v.).

Metakalkuranit. F. Rinne, Centralblatt Min., 1901, p. 709 (Metakalkuranite, *pl.*). Calco-uranite (autunite) from which part of the water has been artificially expelled by heating, thus causing an important series of changes in the optical characters.

Metakoenenite. F. Rinne, Centralblatt Min., 1902, p. 498 (Metakoenenit). Koenenite (q. v.) when heated in water leaves a residue

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having the composition $Al_2O_3 . MgO . H_2O$; with ammonium chloride solution it yields $Al_2O_3 . 2H_2O$, and this on ignition gives anhydrous alumina. These artificially produced secondary products ('metakoenenites') retain the scaly form of the original mineral, and are optically uniaxial and negative.

Metakupferuranit. F. Rinne, Centralblatt Min., 1901, p. 618 (Metakupferuranite, *pl.*). Cupro-uranite (torbernite) from which part of the water has been artificially expelled by heating, thus causing an important series of changes in the optical characters. *See* metachalcolite.

Microlepidolite. *See* macrolepidolite.

Mohawk-algodonite. G. A. Koenig, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 414, 416. Massive copper arsenides from the Mohawk mine, Michigan, of variable composition, but approximating to that of algodonite. *See* mohawkite.

Mohawkite. J. R. Stanton, Engin. and Mining Journ. New York, 1900 (April), vol. lxix, p. 413. A massive copper arsenide, with some cobalt and nickel, from the Mohawk mine, Michigan. Ledoux deduced from his analysis the formula $(Cu,Ni,Co)_4As$. This was afterwards re-named ledouxite (q. v.).

G. A. Koenig, Amer. Journ. Sci., 1900 (December), ser. 4, vol. x, p. 440; Zeits. Kryst. Min., 1901, vol. xxxiv, p. 67. A nickeliferous and cobaltiferous domeykite, $(Cu,Ni,Co)_3As$, from the Mohawk mine. The copper arsenides from this locality show wide variations in composition, and, as pointed out by Koenig, are mixtures, or more of the nature of alloys rather than definite mineral species; nevertheless this author has introduced for them several other new names, viz.:—keweenawite, mohawk-algodonite, mohawk-whitneyite, and semi-whitneyite (q. v.).

Mohawk-whitneyite. G. A. Koenig, Amer. Journ. Sci., 1900, ser. 4, vol. x, p. 446; Zeits. Kryst. Min., 1901, vol. xxxiv, p. 75 (Mohawkit-Whithneyit); Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 414, 416. Intimate mixtures of mohawkite and whitneyite from the Mohawk mine, Michigan. *See* mohawkite.

Moldavite. P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, p. 144; Anal. Acad. Române, Bukarest, 1900, vol. xii. Earlier used by Cobalcescu [reference?] as a specific name for ozocerite, and later by C. Istrati (1897) [who, however, spells the word moldovite] for a variety of ozocerite from Moldavia (Moldova).

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Molybdophyllite. G. Flink, Bull. Geol. Inst. Univ. Upsala, 1901, vol. v (1900), p. 91 (Molybdophyllit). Platy masses with a perfect basal cleavage, and having quite the appearance of white mica. Found with hausmannite in granular limestone or dolomite at Långban, Sweden. Hexagonal. $2(Pb,Mg)O.SiO_2.H_2O$. Differs from barysilite in containing water. Named from *μόλυβδος*, lead, and *φύλλον*, a leaf.

Montroydite. A. J. Moses, Amer. Journ. Sci., 1903, ser. 4, vol. xvi, p. 259. Orthorhombic mercuric oxide, HgO, occurring as velvety encrustations of orange-red needles on mercury-ores at Terlingua, Texas. Named after Mr. Montroyd Sharpe, one of the owners of the mines.

Mooraboolite. G. B. Pritchard, Victorian Naturalist, 1901, vol. xviii, p. 63. A zeolite occurring as white, radial aggregates in the decomposed basalt of the Moorabool valley, Victoria. In chemical composition, and in the crystallographic and physical characters as far as determined, it agrees with natrolite.

Mouchketovite. Ann. Géol. et Min. Russie, 1901, vol. iv, sect. iii, p. 107 (Mouchkétovite, Мушкетовитъ). The same as muschketowit (E. S. Fedorov and W. Nikitin, 1899).

Narsasukite. G. Flink, Meddelelser om Grönland, 1901, Hefte xxiv, plate VIII, and p. 154 footnote. Error for narsarsukite.

Natroalunite. W. F. Hillebrand and S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 218, 220; Zeits. Kryst. Min., 1902, vol. xxxvi, pp. 552, 554. Alunite with part of the potash replaced by soda; in material from Colorado $K_2O : Na_2O = 4 : 7$. $(Na,K)_2[Al(OH)_2]_6(SO_4)_4$. Rhombohedral.

Natrojarosite. W. F. Hillebrand and S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 211; Zeits. Kryst. Min., 1902, vol. xxxvi, p. 545. A yellowish-brown, glistening powder consisting wholly of minute, perfectly developed rhombohedra with basal planes. $Na_2[Fe(OH_2]_6(SO_4)_4$. From Soda Springs Valley, Nevada.

Natronkalisimonyit. R. Köchlin, Min. petr. Mitt. (Tschermak), 1902, vol. xxi, p. 356. A provisional name for crystals agreeing with blödite (simonyite) in form, but apparently differing slightly in chemical composition: in addition to soda, a little potash (0·43 per cent.) is present, and more water is expelled at 100° C. than from typical blödite. From the salt deposits of Kalusz, Galicia.

Natronphlogopit. E. Weinschenk, Abhandl. Akad. Wiss. München,

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1901, vol. xxi, p. 272. A white mica containing magnesia and soda (and potash) in crystalline limestone from Styria.

Neotantalite. P. Termier, Bull. Soc. franç. Min., 1902, vol. xxv, p. 34 (Néotantalite). Minute, regular octahedra resembling pyrochlore, in kaolin from dép. Allier, France. Hydrated tantalate (and niobate) of iron, manganese, and alkalies. Considered to be a dimorphous form of tantalite, but differs considerably from this in composition.

Oonachatae. *See* discachatae.

Orthoaugite. F. Rinne, Sitz.-ber. Akad. Wiss. Berlin, 1900, p. 482 (Orthoaugit). A collective name for the orthorhombic pyroxenes, enstatite, bronzite, and hypersthene, which cannot always be distinguished from each other in rock-sections. Similarly, monoclinic pyroxenes are called clinoaugites (Klinoaugite).

Following Rinne, E. Düll (Zeits. Kryst. Min., 1902, vol. xxxvi, p. 654 footnote, abstract) proposes the terms ortho-pyroxene and klino-pyroxene, abbreviated as o-pyroxene and kl-pyroxene.

Palacheite. A. S. Eakle, Bull. Dep. Geol. Univ. California, 1903, vol. iii, p. 231. Loosely coherent aggregates of brick-red, monoclinic crystals, found as a recent formation in the old workings of the Redington mercury mine, Knoxville, California. $2MgO.Fe_2O_3.4SO_3.15H_2O$. It is not proved to differ essentially from the imperfectly determined rubrite. Named after Dr. Charles Palache, of Harvard University.

Petricichite. P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, p. 143; Anal. Acad. Române, Bukarest, 1900, vol. xxii. Error (?) for pietricikite, which is given by C. Istrati (Bull. Soc. Sci. Bukarest, 1897, vol. vi, p. 65) as the correct spelling of Dana's zietrisikite. A variety of ozocerite from Mount Pietricica, Moldavia.

Petterdite. W. H. Twelvetrees, Rep. Secr. Mines, Tasmania, for 1900–1, 1901, p. 356; Papers and Proc. Roy. Soc. Tasmania, for 1900–1, 1902, p. 51. An oxychloride of lead occurring in Tasmania as white, thin hexagonal plates. Named after Mr. W. F. Petterd, of Launceston, Tasmania.

Pigeonite. A. N. Winchell, Amer. Geologist, 1900, vol. xxvi, pp. 204, 368; Thèse Fac. des Sci. Paris, 1900. A pyroxene, with optic axial angle small and variable ($2E = 13° 16' - 62° 24'$), occurring as a constituent of olivine-diabase at Pigeon Point, Minnesota.

Plumbojarosite. W. F. Hillebrand and S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 218; Zeits. Kryst. Min., 1902, vol. xxxvi,

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p. 548. A dark-brown, glistening powder consisting wholly of minute, perfectly developed rhombohedra with basal planes. $Pb[Fe(OH)_2]_6(SO_4)_4$. From Cook's Peak, New Mexico.

Plumbomalachite. S. F. Glinka and I. A. Antipov, St. Peterburg, Dnevn. XI Sjezda russ. jest. vrač., 1901, p. 468 (свинцовомъ малахитъ). *See* Bleimalachit, malachite de plomb.

Porcupine-ore. *See* histrixite.

Pseudomesolite. A. N. Winchell, Amer. Geologist, 1900, vol. xxvi, pp. 275, 372; Thèse Fac. des Sci. Paris, 1900. A zeolite agreeing with mesolite in chemical composition, but differing in optical characters. Occurs as colourless to white, radially fibrous masses in plagioclasite in Minnesota.

Pseudophillipsite. F. Zambonini, Neues Jahrb. Min., 1902, vol. ii, p. 73 (Pseudophillipsit). A zeolite, from the leucitic lavas near Rome, agreeing with phillipsite in form and twinning (though octahedral in habit, like gismondite), but containing less silica (38 per cent.) than typical phillipsite: formula, $(Ca,Na_2)_2Al_4Si_8O_{16}.9H_2O$.

Pyknochlorite. J. Fromme, Min. petr. Mitt. (Tschermak), 1903, vol. xxii, p. 62 (Pyknochlorit). A greyish-green, compact chlorite occurring in a quartz and calcite vein in the gabbro of the Radauthal, Harz. It has the same general formula (Sp_2At_4, Tschermak) as clinochlore, but differs from this in containing much more ferrous iron and in its compact (πυκνός) texture.

Revdinite. E. N. Kortkov, Bull. Soc. Ouralienne d'Amateurs des Sci. Nat., 1891-2, vol. xiii, pp. 83, 76 (ревдинитъ). The same as rewdanskit (R. Hermann, 1867); other forms of spelling are: refdanskite, revdanskite, revdinskite, rewdjanskit. An impure hydrous nickel silicate from Revda (= Revdinsk), Urals.

Rickardite. W. E. Ford, Amer. Journ. Sci., 1903, ser. 4, vol. xv, p. 69; Engin. and Min. Journ. New York, 1903, vol. lxxv, p. 113; Chem. News, 1903, vol. lxxxvii, p. 56; Zeits. Kryst. Min., 1903, vol. xxxvii, p. 609. A massive telluride of copper, Cu_4Te_3, with a rich purple colour resembling an iridescent tarnish. From Vulcan, Gunnison Co., Colorado. Named after Mr. T. A. Rickard, of New York. *See* sanfordite.

Sanfordite. Ores and Metals, Denver, Colorado, April, 1903 (Sandfordite in title). A synonym of the earlier name rickardite (q. v.). Named after Mr. Albert B. Sanford, of Denver, who first noticed the mineral in 1901.

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Schertalite. R. W. E. MacIvor, Chem. News, 1902, vol. lxxxv, p. 217. To replace the name muellerite for a phosphate in bat guano from Skipton Caves, Ballarat, Victoria. Small, indistinct crystals with the composition $Mg(NH_4)_2H_2(PO_4)_2 . 4H_2O$. Named after Professor Arnulf Schertal, late of Freiberg, Saxony.

Schokoladenstein. *See* lacroisite.

Sclerospathite. W. F. Petterd, Rep. Secr. Mines, Tasmania, for 1901–2, 1902, p. 297; Papers and Proc. Roy. Soc. Tasmania, for 1902, 1903, p. 27. A hydrated sulphate of iron and chromium, perhaps allied to knoxvillite, occurring as tough (σκληρός), felted masses of short fibres, at Salisbury, Tasmania.

Seligmannite. H. Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, p. 110 (abstract, this vol., p. 205); ibid., 1902, p. 611. R. H. Solly, Min. Mag., 1903, vol. xiii, p. 336. Crystals resembling in general appearance the several sulpharsenites of lead from the Binnenthal dolomite. Orthorhombic, with angles, habit, and twinning similar to those of bournonite, and probably therefore with the composition $Cu_2S . 2PbS . As_2S_3$. Named after Herr Gustav Seligmann, of Coblenz.

Semi-whitneyite. G. A. Koenig, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 416. Massive copper arsenides in which the ratio of Cu : As is variable and very high (up to 30 : 1). *See* mohawkite.

Serendibite. G. T. Prior and A. K. Coomáraswámy, Nature, 1902, vol. lxv, p. 383; Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 420; Min. Mag., 1903, vol. xiii, p. 224. Blue, embedded crystals in the contact-zones between crystalline limestone and granulite. Probably anorthic; with polysynthetic twinning and strong pleochroism.

$$10(Fe,Ca,Mg)O . 5Al_2O_3 . 6SiO_2 . B_2O_3.$$

Named from 'Serendib,' an old Arab name for Ceylon, where the mineral was found.

Serpentin-Asbest. C. F. Naumann, Elem. d. Min., 2nd edit., 1850, p. 284. Synonym of chrysolite.

Silver-analcite, Silver-chabazite. G. Steiger, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 31. Artificial derivatives of analcite and chabazite with silver in place of sodium or calcium.

Speculite. E. H. Liveing, Engin. and Mining Journ., New York, 1903, vol. lxxv, p. 814. A specular gold and silver telluride from Kalgoorlie, Western Australia, resembling sylvanite in colour and perfect cleavage, but differing from this in chemical composition (Au 36, Ag 4 per cent.) and sp. gr. (8·64).

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Stagmalite. O. C. Farrington, Field Columbian Museum, Chicago, Publication 53, Geol. Ser., 1901, vol. i, p. 261 (Stagmalites). A general term, to include both stalactite and stalagmite, for formations produced by dropping water. From στάγμα, a drop, and λίθος, a stone.

Steenstrupite. O. B. Boeggild, Meddelelser om Grönland, 1901, vol. xxiv, p. 203. The same as steenstrupine.

Stibio-domeykite. G. A. Koenig, Amer. Journ. Sci., 1900, ser. 4, vol. x, p. 445; Zeits. Kryst. Min., 1901, vol. xxxiv, p. 67. Massive domeykite containing a small amount of antimony (0·78 to 1·29 per cent.). From the Mohawk mine, Lake Superior copper region.

Stibio-luzonite. *See* antimon-luzonite.

Stoffertite. C. Klein, Sitz.-ber. Akad. Wiss. Berlin, 1901, p. 722 (Stoffertit). Differs from brushite ($HCaPO_4 . 2H_2O$) only in containing a little more water ($HCaPO_4 . 2\frac{3}{4}H_2O$). This difference is probably not essential, but, in case it should at some future time be proved to be so, the new name is provisionally given. From the guano deposits of the island of Mona, Porto Rico, West Indies. Named after Dr. Adolph Stoffert, of Hamburg, who sent the material for examination.

Sulfurite. F. Rinne, Centralblatt Min., 1902, p. 500 (Sulfurit). Naturally occurring amorphous sulphur. *See* arsensulfurite.

Synchysite. G. Flink, Bull. Geol. Inst. Univ. Upsala, 1901, vol. v (1900), p. 81 (Synchysit); abstract, this vol., p. 207. The mineral from Narsarsuk, Julianehaab, Greenland, previously described as parisite, has characters sufficiently distinct from those of the Colombian parisite to be regarded as a distinct species. Hexagonal. $CeFCa(CO_3)_2$. Named from σύγχυσις, confounding.

Taeniolite. Amer. Journ. Sci., 1900, ser. 4, vol. x, p. 324, abstract (Tæniolite). The same as tainiolite (Flink, 1901).

Tamanite. S. P. Popoff, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 267. The same as anapaite (q.v.). Professor Groth, in an editorial footnote (l. c.), calls attention to this identity, but he gives no reason for admitting the later name as a synonym. Named from the locality, Taman peninsula, Black Sea.

Terlinguaite. W. H. Turner, Mining and Scientific Press, San Francisco, July 21, 1900. Yellowish-green crystals on the mercury-ores of Terlingua, Brewster Co., Texas, determined by S. L. Penfield to be an oxychloride of mercury.

A. J. Moses (Amer. Journ. Sci., 1903, ser. 4, vol. xvi, p. 253) distin-

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guishes two oxychlorides of mercury from this locality, which he names eglestonite (q. v.) and terlinguaite. The latter name is applied to monoclinic crystals having the composition Hg_2ClO; these are sulphur-yellow, and alter to olive-green on exposure to light.

Termierite. G. Friedel, Bull. Soc. franç. Min., 1901, vol. xxiv, p. 6 (Termiérite). A clay, resembling halloysite in appearance, with the formula $Al_2O_3 . 6SiO_2 . 18H_2O$. Associated with kaolinite, etc., France. Named after Professor Pierre Termier, of Paris.

Thelotite. C. E. Bertrand and B. Renault, Bull. Soc. Hist. Nat. Autun, 1892, vol. v, pp. 168, 240 (thélotite). An undetermined carbonaceous constituent of Boghead coal from the Thélots pits at Autun.

Vandiestite. (Author?) Described as probably a new species, but without name, by R. Pearce (Colorado Sci. Soc. Bull., 1898, No. 6, p. 4; Proc. [1902], vol. vi, p. 168). The information here given was reproduced, under the name Von Diestite, in a note by E. Cumenge (Bull. Soc. franç. Min., 1899, vol. xxii, p. 25 *bis*): in abstracts of this note the name Diestit (q. v.) has been used. The form vandiestite is given in a dealer's advertisement (Amer. Journ. Sci., November, 1901). A massive telluride of silver, bismuth, gold, and lead, from Sierra Blanca, Colorado. Named after Mr. P. H. van Diest, of San Luis, Colorado, by whom the mineral was found.

Vanthoffite. K. Kubierschky, Sitz.-ber. Akad. Wiss. Berlin, 1902, p. 407 (Vanthoffit). The results of several analyses of an apparently homogeneous specimen, from the salt deposits of Wilhelmshall near Stassfurt, were plotted as curves, and the compound $8Na_2SO_4 . MgSO_4$ inferred to be present in the mixture of salts. This is colourless, with a vitreous lustre, and a coarsely crystalline structure. Pure material was isolated from another specimen by means of a heavy liquid. The salt $8Na_2SO_4 . MgSO_4$ was afterwards prepared artificially by Professor J. H. van't Hoff, of Berlin, after whom the mineral is named.

Vierzonite. A. de Grossouvre, Bull. Soc. géol. France, 1901, ser. 4, vol. i, p. 432. A. Lacroix, Min. de France, 1901, vol. iii, p. 829. A deposit ('argile à silex') consisting essentially of pulverulent opal, which has been produced by the weathering of Cretaceous beds in the neighbourhood of Vierzon, dép. Cher. The same name has been previously applied to a yellow ochreous clay from the same locality (H. W. Bristow, Glossary of Mineralogy, 1861).

Violaite. E. S. Fedorov, Annales de l'Institut agronomique de

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Moscou, 1901, vol. vii, p. 48 (Віолантъ). A strongly pleochroic pyroxene which forms an essential constituent of a rock called kedabekite from the Kedabek copper-mine, Caucasus. Differs from fedorovite (Viola, 1899) in having a considerable portion of the magnesia replaced by ferrous oxide. Named after Dr. Carlo Viola, of Rome.

Von Diestite. *See* vandiestite.

Weldite. F. M. Krausé, Proc. Roy. Soc. Tasmania, for 1884, 1885, p. lxxv. A silicate of aluminium and sodium, from the Weld river, upper Huon district, Tasmania.

Wiikite. W. Ramsay. Mentioned, but without name, by W. Ramsay and A. Zilliacus, Öfvers. Finska Vetenskaps-Soc. Förhandl., 1897, vol. xxxix, p. 58. The name wiikite appears in a dealer's advertisement (Amer. Journ. Sci., December, 1899). An euxenite-like mineral found with monazite in a felspar-quarry at Impilaks, Lake Lagoda, Finland. Named after Professor F. J. Wiik, of Helsingfors.

Zeophyllite. A. Pelikan, Anzeiger Akad. Wiss. Wien, Math.-naturw. Cl., 1902, Jahrg. xxxix, p. 118; Sitz.-ber., 1902, vol. cxi, Abth. I, p. 336 (Zeophyllit). A zeolite containing fluorine; $H_4Ca_4F_2Si_3O_{11}$. It occurs at Gross-Priesen, Bohemia, as hemispherical and spherical aggregates of small plates with a perfect cleavage and pearly lustre. Named from ζεῖν, to boil, and φύλλον, a leaf.

Zinc-römerite. R. Scharizer, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 546 (Zinkrömerit). Römerite in which ferrous iron is replaced by zinc. In the natural mineral, from the Harz, this replacement is only partial, but it is more complete in an artificial product.

SYSTEMATIC CLASSIFICATION OF NEW MINERALS[1].

Elements.	Tellurides.
Sulfurite, amorphous S.	Rickardite, Cu_4Te_3.
Arsensulfurite, do. with As.	Speculite, contains Au,Ag.
	Vandiestite, contains Ag,Bi,Au,Pb.
Sulphide.	**Arsenides.**
Chalmersite, $CuFe_2S_4$.	Badenite, $(Co,Ni,Fe)_2(As,Bi)_3$.

[1] Synonyms, names of mixtures, and various indefinite names given in the alphabetical list above are here omitted.

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Keweenawite, $(Cu,Ni,Co)_2As$.
Mohawkite, $(Cu,Ni,Co)_3As$.
Stibio-domeykite, $Cu_3(As,Sb)$.
Ledouxite, $(Cu,Ni,Co)_4As$.
Mohawk-algodonite.
Mohawk-whitneyite.
Semi-whitneyite.

Sulpharsenites, &c.

Liveingite, $Pb_6As_8S_{17}$.
Baumhauerite, $Pb_4As_6S_{13}$.
Seligmannite, $CuPbAsS_3$?
Histrixite,
$7Bi_2S_3 . 2Sb_2S_3 . 5CuFeS_2$?
Antimon-luzonite, $Cu_3(As,Sb)S_4$.

Haloids.

(Mercuric iodide)[1], HgI.
Iodembolite, Ag(Cl,Br,I).
Terlinguaite, Hg_2ClO.
Eglestonite, Hg_6Cl_3O.
Petterdite, oxychloride Pb.
Koenenite,
$Al_2O_3 . 8MgO . 2MgCl_2 . 6H_2O$.

Oxides.

(Cadmium oxide)[2], CdO.
Montroydite, HgO.
Lardite, var. of opal.
Vierzonite, „ „
Hydrogöthite, $3Fe_2O_3 . 4H_2O$.
Esmeraldaite, $Fe_2O_3 . 4H_2O$.
Brostenite, near chalcophanite.

Carbonates.

Erzbergite, calcareous sinter.
Manganosphaerite,
$8FeCO_3 . 2MnCO_3$.
Synchysite, $CeFCa(CO_3)_2$.
Artinite, $MgCO_3 . Mg(OH)_2 . 3H_2O$.
Plumbomalachite,
$2CuCO_3 . Cu(OH)_2 . PbCO_3$.
Melanochalcite,
$Cu_2(Si,C)O_4 . Cu(OH)_2$.

Anhydrous Silicates.

Pigeonite, var. of pyroxene.
Violaite, „ „
Kunzite, violet spodumene.
Bourgeoisite, $CaSiO_3$?
Eisencordierit, var. of cordierite.
Kalkeisencordierit, „
Hackmanite, sodalite group.
Bleizinkchrysolith, $PbZnSiO_4$ (artificial).
Hellandite,
$2CaO . 3(Ce,Al,\&c.)_2O_3 . 4SiO_2$.
Serendibite,
$10(Fe,Ca,Mg)O . 5Al_2O_3 . 6SiO_2 . B_2O_3$.
Grandidierite, contains Al,Fe,Mg, Ca.

Hydrous Silicates.

Macrolepidolite, var. of lepidolite.
Microlepidolite, „ „
Natronphlogopit, var. of phlogopite.
Pyknochlorite, near clinochlore.
Brunsvigite, near metachlorite.
Lassallite,
$3MgO . 2Al_2O_3 . 12SiO_2 . 8H_2O$.
Termierite, $Al_2O_3 . 6SiO_2 . 18H_2O$.

[1] A. J. Moses, Amer. Journ. Sci., 1901, ser. 4, vol. xii, p. 98; Zeits. Kryst. Min., 1902, vol. xxxv, p. 417. Minute scarlet crystals, probably cubic, from Broken Hill, New South Wales.

[2] B. Neumann & E. Wittich, Chemiker-Zeitung, 1901 (July), Jahrg. xxv, p. 561; E. Wittich & B. Neumann, Centralblatt Min., 1901 (September), p. 549; abstract, this vol., p. 308. Cubic octahedra from Monte Poni, Sardinia.

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Lotrite,
$3(Ca,Mg)O . 2Al_2O_3 . 4SiO_2 . 2H_2O$.
Bavenite, $3CaO . Al_2O_3 . 6SiO_2 . H_2O$.
Molybdophyllite,
$2(Pb,Mg)O . SiO_2 . H_2O$.
Bakerite, $8CaO . 5B_2O_3 . 6SiO_2 . 6H_2O$.

Zeolites.

Chromocyclite, var. of apophyllite.
Zeophyllite, $H_4Ca_4F_2Si_3O_{11}$.
Pseudophillipsite,
$(Ca,Na_2)_2Al_4Si_5O_{18} . 9H_2O$.
Pseudomesolite, near mesolite.
Mooraboolite, near natrolite.
Silver-analcite, &c. (artificial).
Ammonium-analcite, &c. „

NIOBATES, &c.

Neotantalite.
Wiikite, near euxenite.

PHOSPHATES, &c.

Anapaite, $FeCa_2(PO_4)_2 . 4H_2O$.
Ceruleite,
$CuO . 2Al_2O_3 . As_2O_5 . 8H_2O$.
Schertalite,
$Mg(NH_4)_2H_2(PO_4)_2 . 4H_2O$.
Stoffertite, $HCaPO_4 . 2\frac{3}{4}H_2O$.
Hörnbergite, uranium arsenate.

SULPHATES.

Ciempozuelite, $3Na_2SO_4 . CaSO_4$.
Vanthoffite, $3Na_2SO_4 . MgSO_4$.
Natroalunite,
$(Na,K)_2[Al(OH)_2]_6(SO_4)_4$.
Natrojarosite,
$Na_2[Fe(OH)_2]_6(SO_4)_4$.
Plumbojarosite,
$Pb[Fe(OH)_2]_6(SO_4)_4$.
Ferropallidite, $FeSO_4 . H_2O$.
Boothite, $CuSO_4 . 7H_2O$.
Natronkalisimonyit, near blödite.
Palacheite,
$2MgO . Fe_2O_3 . 4SO_3 . 15H_2O$.
Zinc-römerite,
$(Fe,Zn)SO_4 . Fe_2(SO_4)_3 . 14H_2O$.

HYDROCARBON.

Thelotite.

September, 1903.

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NOTES.

We regret to record the deaths of the following mineralogists:—

Alphonse François Renard (1842–1903), Professor of Mineralogy and Geology in the University of Ghent. He was an honorary member of this Society, and was well known in England both personally and by reason of his work on deep-sea deposits and petrology in the 'Challenger' reports.

Albert Huntington Chester (1843–1903), Professor of Chemistry and Mineralogy in Rutgers College, New Brunswick (New Jersey). His extremely valuable 'Dictionary of the Names of Minerals,' published in 1896, will keep his name long in the minds of mineralogists. He had been a member of this Society since 1887.

Luigi Bombicci-Porta (1833–1903), since 1860 Professor of Mineralogy in the University of Bologna. He was a prolific writer on mineralogical subjects.

Johann Theodor Lemberg (1842–1903), Professor of Mineralogy and Geology in the University of Dorpat. The chemical action of reagents on silicates and the micro-chemical examination of minerals were his special studies.

A famous collection of minerals, which till now has remained in the possession of the Rashleigh family at Menabilly, Cornwall, has recently (1903) been acquired, partly by presentation and partly by purchase, by the Museum of the Royal Institution of Cornwall at Truro, the principal donor being Mr. J. D. Enys. The collection is particularly rich in rare old Cornish minerals, and many of the specimens are unique. A quarto volume of coloured plates with brief descriptions—'Specimens of British Minerals selected from the cabinet of Philip Rashleigh'—was published in 1797 and 1802, and contains the earliest descriptions extant of certain well-known Cornish minerals, for example, bournonite and connellite.

The private collection of South American minerals brought together by the late Theodor Hohmann (1843–1897), of Chile, after whom the mineral hohmannite receives its name, has been sent to this country for sale, and a large selection has been made for the British Museum. Specially noteworthy are fine crystallized specimens of rare minerals from Sierra Gorda in Chile, namely, percylite, atacamite, caracolite, paralaurionite, schwartzembergite, &c., the last named being in well-developed tetragonal crystals.

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An authors' catalogue and subject index of mineralogical (including petrological and crystallographic) books and papers published in 1901 has been issued as one of the volumes of the International Catalogue of Scientific Literature. With the subject-key in four languages and a list of journals indexed, the volume extends to 208 pages. Owing to the difficulties of organizing the work, the index is very incomplete, there being only two parts of 'Groth's Zeitschrift' included, and none of the 'Centralblatt für Mineralogie, &c.,' or 'Tschermak's Mineralogische Mitteilungen'; on the other hand, German technical journals have been very fully dealt with. Economic literature, indeed, has been indexed much more fully than the scope originally intended for the catalogue would warrant, but this may possibly add to its usefulness. The topographical arrangement of both scientific and economic titles will certainly be found of use.

A complete and fully illustrated treatise on the regular intergrowth of minerals of different species is given by Professor O. Mügge in the 'Neues Jahrbuch für Mineralogie, &c.' (1903, Beil.-Bd. xvi, pp. 335–475, with 82 figs.). The labour of compilation must have been considerable, and have involved an exhaustive search of mineralogical literature, for the facts here brought together are in many cases mentioned only casually in papers. The tabular classification and index now given will greatly facilitate reference to the subject. Seventy-two well-established cases of regular intergrowth are described in detail, while many more receive mention. A general discussion of the subject is appended.

Another paper, covering much the same ground, was published a few months earlier (F. Wallerant, Bull. Soc. franç. Min., 1902, vol. xxv, pp. 180–222, with 26 figs.).

REVIEWS.

Mineralogy: an Introduction to the Scientific Study of Minerals. By Henry A. Miers, D.Sc., M.A., F.R.S. Pp. xviii + 584, with two coloured plates and 716 illustrations in the text. (London: Macmillan & Co., Ltd., 1902. Price 25*s.* net.)

Since the study of minerals must be conducted by means of their chemical, physical, and morphological characters, it follows that it can

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only be successfully undertaken by those already tolerably grounded in the elements of chemistry, physics, and crystallography. The recognition of this fact has led to the preparation of numerous treatises possessing the common feature of an elaborate introduction in which the student is provided with all that it is considered necessary for him to know of cognate branches of science. Among the most widely circulated and successful of the attempts made in this direction the 'Text-Book of Mineralogy' by Professor E. S. Dana has taken an honourable place, and English-speaking students are now to be congratulated on the possession of another excellent handbook following much the same lines.

The work before us is divided into two parts of approximately equal length. The first hundred pages of Part I are devoted to the definition of a crystal and to the exposition of the fundamental laws of crystallography, and include a description of the characteristic properties of the thirty-two crystal sub-classes. The next hundred pages deal with the measurement of crystals and with their optical properties. The remaining chapters of Part I are occupied by an account of the chemical principles involved in mineral analysis, and include also a discussion of isomorphism, definitions of the terms, such as hardness, lustre, &c., used in describing minerals, and directions for performing simple chemical tests. Two appendices conclude this part of the book, and contain a synopsis of the thirty-two crystal sub-classes and a very brief outline of the theory of crystal structure.

In an elementary work of this kind no great originality of treatment is to be looked for, nor is indeed possible, when the author is dealing with branches of science in which the main tracks are already so clearly marked out, and when his aim, from the nature of the case, must be chiefly directed to securing as much compression as is consistent with clearness of exposition. Nevertheless, there are several features in this book which claim special attention. In the first place all crystallographers, however little they may be disposed to accept his suggestions, must feel grateful to Professor Miers for his efforts to reduce to order the names of the thirty-two crystal sub-classes. A system of nomenclature elaborated by the author in consultation with Professor Dana cannot fail to claim respect, if indeed it does not carry conviction to all, though doubtless there will be found some to regret the fusion of the rhombohedral with the hexagonal system. Another interesting and novel feature is the application of colour-photography to the delineation of the optical phenomena presented by crystal-sections. A glance at the two plates at the end of the book will cause the reader to regret that con-

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siderations of expense prevented the wider application of the process. A third point worthy of attention is the completeness of the work. In it an account will be found, brief it may be, of all the essential properties of crystals. This feature is at once both the strength of the book and also a source of weakness, for it is inevitable that obscurities must occur when subjects which might fitly demand a treatise in themselves are dealt with in the course of a hundred pages. Thus the chapter on optics will be found difficult reading by the elementary student; it seems indeed doubtful if the most attentive perusal will give him accurate ideas as to the polarization produced when light is reflected and refracted by a plate of glass, or as to the cause of the colour-phenomena exhibited by thin crystal-plates viewed in parallel white light between crossed nicols.

While in Part I Professor Miers has achieved all the success that the difficulty of his task permitted, it is in Part II, which deals with descriptive mineralogy, that we find the freshness of treatment which differentiates this book from all others of its class. Too often descriptive mineralogy is treated as a catalogue of the driest facts presented in bewildering number to the eye of the disheartened learner, who is speedily wearied and finally repelled. Professor Miers has chosen a more excellent way. He concentrates the beginner's attention on one or two of the more important and characteristic occurrences of each mineral species, and brings them vividly before his eye, not merely in the shape of the ideal figures of the crystallographer, but also by means of the admirable series of sketches drawn from actual specimens which we owe to the skilful pencil of Miss J. Miers. Where all are so good it is difficult to single out any for special praise, but attention may be called to the drawings of cassiterite and of microcline (pages 361 and 460). A comparison of these pictures with the photographs of calcite, on pages 397 and 398, will speedily convince the most sceptical that there are regions in which the camera cannot compete with the seeing eye and the well-trained hand. No attempt has been made to deal in detail with the rarer minerals, but they are duly inserted in the most valuable tables, last in place but by no means in importance, with which the book concludes. Here we find the minerals arranged according to their chemical composition, and also in order of their refractive indices, birefringences, optic axial angles, and specific gravities. The printer has done his part admirably; there is an excellent index, and the appearance of the book leaves nothing to be desired. It will be found invaluable by teacher and student alike.

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The Diamond Mines of South Africa: some account of their rise and development. By Gardner F. Williams, M.A., General Manager of the De Beers Consolidated Mines, Ltd. Pp. xviii + 681. Royal 8vo. (New York: The Macmillan Company; London: Macmillan & Co., Ltd., 1902. Price £2 2*s.* = $10.00 net.)

THIS handsomely got up and profusely illustrated volume contains much that will be of interest to the general public, and being written by the General Manager of the De Beers Consolidated Mines, may be regarded as authoritative when dealing with the operations of this influential Company. Much, however, of the matter contained in the book, though interesting in itself, has little or no direct bearing on the subject indicated in the title. On the other hand, very little is said of those diamond mines of South Africa not directly controlled by the De Beers Company, some indeed being not even mentioned.

The first 119 pages are devoted to a general discourse on the diamond, its mention in ancient writings, the stories associated with famous stones, the discovery and opening up of South Africa, and finally the finding of diamond there in 1867. Then follow graphic accounts of the diggings on the Vaal River and the early workings at Kimberley. A very full and detailed description, based largely on the author's personal observations, is given of the later workings, both open and underground, in the De Beers and Kimberley mines, and of the methods employed in extracting the diamond from its matrix. The book concludes, as it began, with 120 pages or so of more or less irrelevant matter dealing with the cutting of diamond, the opening up of the gold-fields of South Africa, and the siege of Kimberley in the late Boer war.

Practically all the volume contains of special mineralogical interest is confined to the chapter on the formation of the diamond. The author holds the view that the diamond-bearing 'blue-ground' is of aqueous rather than of igneous origin, and was erupted into the pipes by mud volcanoes, a view which is supported by the fact that the shales surrounding the pipes and caught up by the 'blue-ground' have not been in the least altered. As to the origin of the diamond, he favours no particular theory, but raises objections to all that have been brought forward, including that which supposes the diamond to have crystallized from a basic silicate-magma, and which has been proved to be practically possible by the experiments of Friedländer (1898), experiments, however, which receive no mention in the book. The author's chief objection to the view just mentioned seems to be based on Luzi's observation that

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crystals of diamond are corroded by molten 'blue-ground.' It might be equally well urged that crystals of salt, being corroded by water, are therefore incapable of separating out from an aqueous solution. It is, however, a notable fact that diamond has never been found enclosed in olivine or in any other mineral, and the intimate association or intergrowth of diamond with other minerals appears to be of extremely rare occurrence. In this connexion a case is here recorded of a diamond enclosing a small octahedron of diamond and some white plates of apophyllite.

The mineralogical information is on the whole unsatisfactory, and contains many minor inaccuracies: for example, the figures of diamond crystals, on p. 534. The technical side relating to the methods of mining and washing might also have been much more complete. The book is popular in style, and its most striking feature is the wealth of illustrations, which include several excellent photogravures. These, however, are not arranged with regard to the accompanying text, and in some cases have no reference to it whatever. Several ancient maps of the African continent are given, and a plan of the De Beers group of mines at Kimberley, but no map to illustrate the distribution of diamond in South Africa.

Mathematical Crystallography and the Theory of Groups of Movements. By Harold Hilton, M.A. Pp. xii + 262, with 188 figures in the text. (Oxford: at the Clarendon Press, 1903. Price 14*s.* net.)

The British Association Report on 'The Structure of Crystals' (1901) gives a full historical account of the development of the geometrical theory; but such a survey is necessarily lacking in detailed reasoning. The gap is now filled by Mr. Hilton's admirable book. Its scope is perhaps more accurately indicated by the subsidiary than by the main title, since it is almost wholly concerned with the symmetry and structure of crystals. Although in his preface the author modestly disclaims any originality, and points out that in Part II (and to some extent, we may remark, in Part I also) he follows the lines of Schönflies's 'Krystallsysteme und Krystallstructur,' adopting here and there features from the writings of Barlow, Jordan, and Fedorow, the book is by no means a slavish copy of the original. A great improvement is effected by the excellent diagrams of the space-groups, which have been independently drawn on the methods suggested by Fedorow. The absence of such diagrams in Schönflies's book undoubtedly adds greatly to the difficulty of following his reasoning. Mr. Hilton might with advantage have pointed out that underlying each of the 230 groups there is, besides the

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lattice, a Sohncke-system. Many readers, who have had no previous acquaintance with the theory of groups, might find this (Barlow's) method the easiest way of approaching the subject.

Part I is mainly occupied with the derivation of the thirty-two point-groups, which obey the law of rational indices and are therefore alone applicable to crystals. It also contains an interesting chapter on the growth of crystals. It seems indeed probable that it is by means of observations on growing crystals that the elusive clue to the problem of the connexion between crystal form and chemical composition will eventually be found. The sequence adopted in Part II is precisely that of Schönflies: after establishing the fourteen lattices, Mr. Hilton discusses the properties of geometrical operations, and proves the fundamental proposition that each space-group is isomorphous with one of the thirty-two point-groups and all the operations of the point-group are symmetry-operations of some space-lattice. The systematic application of this property determines the 230 groups. Towards the end of the book is a discussion of the partitioning of space and of Schönflies's elementary cell. Mr. Hilton has indeed handled with ease and skill a subject which, like all dealing with three dimensions, is with difficulty rendered intelligible. We must not omit a word of commendation to the Delegates of the Press for their enterprise in publishing a book which can appeal only to a limited few, and for the excellent way in which the printing has been executed.

Ueber Harmonie und Complication. Von Dr. Victor Goldschmidt. Pp. iv + 186, with 28 figures in the text. (Berlin: Julius Springer, 1901.)

Perhaps the most marked feature of recent development of science is the tendency to remove the artificial barriers between the various branches and the merging of the one into the other at their mutual boundaries. Any attempt to co-ordinate the principles underlying the different subjects cannot fail to be of interest, even if not convincing. At first sight it might indeed appear absurd to imagine any possible connexion between subjects so different as crystallography, music, and spectrum analysis; nevertheless a perusal of Professor Goldschmidt's book will convince the careful reader that the co-ordination which he traces is not to be idly dismissed.

Professor Goldschmidt's name is well known to crystallographers. For some years past he has published in the 'Zeits. für Kryst. und Min.' papers dealing with the law of complication, as he interprets Haüy's

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crystalline law, in the course of which he shows that the symbols which may be assigned to crystal faces fall into certain groups. This law forms the basis of the present work and is explained in the opening pages. We will quote the following table :—

Primary faces :	A							B	= Normal row 0.
N_0 =	0							∞	
1 complication :	A				C			B	= Normal row 1.
N_1 =	0				1			∞	
2 complication :	A		D		C		E	B	= Normal row 2.
N_2 =	0		$\frac{1}{2}$		1		2	∞	
3 complication :	A	F	D	G	C	H	E	I B	= Normal row 3.
N_3 =	0	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	$\frac{3}{2}$	2	3 ∞	

A, B, C, &c., represent faces lying in the same zone, and the numbers underneath each represent the corresponding indices, which have been arithmetically transformed so as to make the extremes 0 and ∞ instead of, as usual, 0 and 1. Professor Goldschmidt asserts that, if A, B, and C are properly selected, we obtain a series of groups [DE], [FGHI], &c. The faces become rarer as the symbol increases in complexity, and those in each group are likely to appear together. Each of the rows is derived from the preceding in precisely the same way. Thus 0 1 ∞ can be transformed into 0 $\frac{1}{2}$ 1 and 1 2 ∞. The indices of commonly occurring faces rarely exceed those given by the third complication.

Similar series may be obtained from the pitch numbers of the notes constituting a musical scale. Thus in the case of the major scale of C we have :—

c	*d*	*e*	*f*	*g*	*a*	*b*	$\bar{c}$
1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
0	$\frac{1}{7}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2	7	∞

where the last row is obtained from the preceding by arithmetical transformation. Two notes, *d* and *b*, have numbers higher than those given by the third complication. These must be excluded because, as the author very plausibly remarks, they really belong to the chord of the dominant, *g*, being respectively the fifth and the third. The third complication gives the following scale :—

c	*e*	*f*	*f*♯	*g*	*a*♭	*a*	*b*♭	$\bar{c}$
1	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{7}{5}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{5}{3}$	$\frac{7}{4}$	2
0	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	$\frac{3}{2}$	2	3	∞

b♭ forms the modulation to the chord of the sub-dominant and is of

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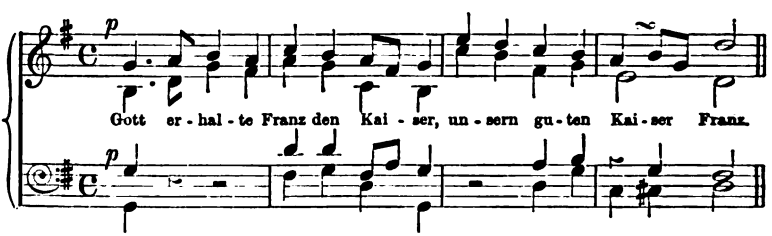
great importance in the key of C. The remaining pair are not of such frequent occurrence. The author remarks that often in crystals and in colour phenomena the development lies between two normal rows. It is a remarkable discovery that the minor scale is, so to speak, the reflection of the major; thus we have:—

Rising harmony, major scale:	c	e	f	g	a	$\bar{c}$
	0	$\frac{1}{3}$	$\frac{1}{2}$	1	2	∞
Falling harmony, minor scale:	$\bar{c}$	$a\flat$	g	f	$e\flat$	c
	0	$\bar{1}$	$\bar{\frac{1}{2}}$	$\bar{1}$	$\bar{2}$	$\overline{\infty}$

The development from other ground-tones selected from the scale is discussed and the resulting tones are compared with those belonging to the original scale. Equal temperament is touched upon and its justification pointed out. Certain examples of classical music are studied in detail. As an instance of his method, we quote his analysis of Haydn's well-known hymn:—

Gott	er-	hal-	te	Franz	den	Kai	-	ser,	un-sern	gu-ten	Kai	-	ser	Franz.
g	a	b	a	c	b	a		$f\sharp$ g	e	d	c	b	a b	g d
b	d	g	$f\sharp$	a	g	c		c b	c	b	$f\sharp$	g	e e	e d
g	..	..	..	d	d	$f\sharp$		a g	..	..	a	b	.. g	g $f\sharp$
g	..	..	..	$f\sharp$	g	d		d g	..	..	d	g	c $c\sharp$	$c\sharp$ d
0 $\frac{1}{3}$	01	0 $\frac{1}{3}$	$\frac{1}{3}$ 1	0 $\frac{1}{3}$	13	0 $\frac{1}{3}$	1	0 $\frac{1}{3}$ 13 0 $\frac{1}{3}$	0 $\frac{1}{3}$	$\frac{1}{3}$ 1	0 $\frac{1}{3}$	13	0 $\frac{1}{3}$	0 $\frac{1}{3}$ 2 0 $\frac{1}{3}$ $\frac{2}{3}$ 2 0 $\frac{1}{3}$
g	d	g	d	d	g	d	d	g	c	g	d	g	c g	g d

g d g c d

0 1 0 $\frac{1}{2}$ 1

g

Thus it will be seen that no numbers occur exceeding those given by the third complication.

In the next chapter will be found an interesting discussion of the physiological and psychological grounds for the harmony of tones.

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Helmholtz was of opinion that Corti's organ renders possible the discrimination of sounds; but, as Professor Goldschmidt points out, it is difficult to account in this way for the almost infinite gradations of tone that are appreciable by an educated ear. He himself thinks that the tympanum plays an important part. The appreciation of musical sounds, as apart from noise, depends on the brain; that there is some connexion is shown by the fact that we can think and dream of tones.

An exceedingly interesting chapter is that dealing with the harmony of colours. The author shows that the wave-lengths of the principal Fraunhofer lines, with the exception of G, agree with the third complication, and that the same is true of the hydrogen lines. The occurrence of the octave in the lines of the spectra of the elements has frequently been observed; the idea that they form an harmonious series is suggestive and worthy of further study. The author discusses fully the various theories of colour vision, especially that of Young and Helmholtz. The exhaustive history of the development of colour vision testifies to his painstaking research. Recent work among the primitive races still existing confirms the correctness of his view, that in early days man possessed little discrimination of colour.

The book closes with a discussion of other evidence of the law in nature, such as is given, for instance, by the characters of organisms, by the systems of numbers, by the monetary systems, and so on. It is however impossible within the limits of a review to enter into these in detail.

Professor Goldschmidt may be congratulated on the production of a thoughtful and philosophical work. Ranging, as it does, over such a diversity of subjects, it is indeed a formidable task to be attempted single-handed. Whether the views expressed are correct or not, it is in the present state of our knowledge perhaps impossible to decide. There can, however, be no doubt as to the value of such a book in calling attention to, and throwing light on, the possibility of the co-ordination of fundamental principles.

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ABSTRACTS.

Ueber den Einfluss der Lösungsgenossen auf die Krystallisation des Calciumcarbonates (Heinrich Vater, in Tharandt, Saxony). Zeits. Kryst. Min., 1893-9, vol. xxi, pp. 438-490; xxii, 209-228; xxiv, 366-404; xxvii, 477-504; xxx, 295-298, 485-508; xxxi, 538-578).

PART I.—The aim of these researches is to throw light on the conditions which determine the 'habit' of crystals, with the ultimate object of enabling us to prepare minerals artificially in the forms which they exhibit in their various occurrences, and so to lay a foundation on which conclusions as to their modes of formation in nature may be based. Owing to the number of its forms, its dimorphism, and its wide distribution, calcium carbonate was selected for study, and the influence on its crystallization of other substances present in solution at the time of its deposition (co-solutes) was investigated.

From a consideration of the work of his predecessors, of which he gives an historical summary, the author was led to investigate first the deposition of $CaCO_3$ at ordinary temperatures from solution in water containing CO_2, and found that the sole product was calcite in fundamental rhombohedra, *R*. The study of the influence of co-solutes was next begun. It was found that the best crystals were got by diffusion, and after preliminary experiments the following method was adopted. A dish 85 mm. in diameter and 40 mm. high was placed inside another 135 mm. in diameter and 60 mm. high; one-fifth gram-equivalent of a soluble calcium salt and of an alkaline bicarbonate were dissolved in small quantities of water saturated with CO_2 and placed in the inner and outer dishes respectively, the dishes were then filled up with water saturated with CO_2, covered, and diffusion allowed to go on. Under these conditions the crystallization of the $CaCO_3$ proceeds under the influence of the soluble salt formed by the action of the bicarbonate on the calcium salt. If it was desired to increase the amount of the co-solute, or to study the effect of some other foreign substance, the necessary compounds were added to the water. After some days crystals separated, chiefly round the small dish—inside it towards its rim (these are usually the best), outside it, on its bottom, and clinging to the water surface above it.

Experiments made as above, using $CaCl_2$ and $Ca(NO_3)_2$ with $KHCO_3$ and $NaHCO_3$ respectively, gave calcite only, showing combinations of

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the forms R and steep negative rhombohedra $-mR$ (measurable in some cases, $-6R$ being common). The addition of KCl or NaCl to the water merely altered the value of m. On using stronger solutions of $CaCl_2$ and of $KHCO_3$ crystals in the form $-mR$ were found, m being greatest for crystals deposited furthest from the inner dish. Experiments with $CaCl_2$ and $KHCO_3$ in which gypsum was added to the water gave calcite only, with $-mR$ largely developed. Addition of a small quantity of $BaCl_2$ to the solution produced mixed crystals containing up to 9% $BaCO_3$, and having the form of calcite ($-mR$ with base). Hemispherical aggregates composed of radially arranged fibres were also formed. The optical behaviour of these fibres suggests that they are anorthic or oblique, they contain $BaCO_3$ in small quantities, are converted into calcite when heated to low redness, their sp. gr. is 2·56, and they are believed by the author to be a new form of calcium carbonate.

Two further series of experiments were made by adding $CaCl_2$, $Ca(NO_3)_2$, $KHCO_3$, $NaHCO_3$, KCl, NaCl, KNO_3, and $NaNO_3$ respectively, in quantities of one-fifth gram-equivalent per litre, and of one gram-equivalent per litre, to water saturated with $CaCO_3$ and CO_2. On allowing to stand at 5°–18° C. crystals similar to those got by diffusion and exhibiting R and $-mR$ were obtained.

From these experiments the author concludes that R is the form in which calcite crystallizes from pure solutions, the occurrence of other forms depending on the presence of co-solutes; the development of a particular form depending further on the nature and concentration of the co-solutes and on the velocity of crystallization.

II.—Since G. Rose and Credner both state that a solution of $CaCO_3$ in water containing CO_2 which deposits calcite at first, yields aragonite on standing, the author made a careful study of the crystallization of $CaCO_3$ under these conditions. Preliminary experiments in which the calcite formed was filtered off, and in which drops of solutions of various strengths were allowed to evaporate, gave only rhombohedra of calcite when dilute solutions were used, and calcite crystals together with disc-like bodies when the solutions were stronger. Next ten solutions were prepared, containing from 0·5 to 0·05 gram of $CaCO_3$ per litre, and these allowed to evaporate at temperatures of from 5° to 20° C. The product in all cases was calcite in the form R. The crystals deposited after long standing showed traces of modifications probably due to the influence of silicates dissolved from the glass vessels, as a solution made with water previously boiled in a glass vessel behaved similarly. Certain rod-like bodies found in some of the solutions, and thought at first to be

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aragonite prisms, proved to be bacteria. These results do not confirm the statements of Rose and Credner.

III.—In some of the diffusion and evaporation experiments described in Part I, exceptionally large crystals of a yellow colour were found on the bottom of the small dish. The colour was traced to organic matter, probably derived from the alkaline bicarbonate. On repeating the experiments with fresh chemicals no such crystals were obtained except when K_2SO_4 (a substance specially liable to be contaminated by organic matter) was added as a co-solute.

IV.—Since Rose stated that aragonite was produced both on evaporation at ordinary temperatures of water containing $CaCO_3$ and CO_2, and also when solutions of $CaCl_2$ and Na_2CO_3 were allowed to diffuse, and as the author's experiments so far described are not in accordance with these statements, a careful repetition of the diffusion experiments was undertaken. Pure solutions of $CaCl_2$ and of Na_2CO_3 were allowed to diffuse into one another in the presence of much water in such quantity that only a little $CaCO_3$ was formed; this proved to be calcite. In one experiment sheaf-like crystal aggregates and round discs were found as well as good crystals of calcite. The aggregates are tinted yellow by organic matter, they are built up of fibres giving straight extinction, consist of $CaCO_3$, and have the sp. gr. of calcite. The author thinks that the presence of organic matter causes the production of these fibrous aggregates, and believes that Rose mistook them for aragonite.

V.—The disc-shaped crystallites of $CaCO_3$ have already been observed by Link, Rose, and others. The author met with them often in the crystalline crust formed on the surface of the liquid when water containing $CaCO_3$ and CO_2 was evaporated. The discs are formed at the same time as the crystals of calcite, and frequently redissolve as evaporation proceeds. They are usually colourless and consist of $CaCO_3$. The sp. gr. is a little lower than that of calcite. The addition of various co-solutes had no influence on their formation, but they were deposited most readily from strong solutions of $CaCO_3$ containing but slight excess of CO_2. Though the author has been unable to trace the cause of their production with certainty, he attributes it to the presence of slight traces of some unknown impurity in the $CaCO_3$ from which the solution was prepared.

VI.—The experiments described in this section show that unless the concentration of a co-solute exceeds a certain value it has no effect on the crystallization. Thus the presence of 0·005 gram-equivalents of NaCl per litre has no effect on the deposition of calcite, which crystal-

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lizes in fundamental rhombohedra R, whereas the influence of 0·13 gram-equivalents is decided, the crystals showing the forms R with $-mR$ ($m = 8$). The author concludes, moreover, that there is also an upper limit beyond which the further addition of the co-solute produces no effect.

VII.—As Credner reported the formation of aragonite as well as of calcite on the evaporation of water containing $CaSO_4$ in addition to $CaCO_3$ and CO_2, the author studied the influence of various sulphates present as co-solutes. Calcite only was formed on allowing a solution of an alkaline bicarbonate to diffuse into a calcium solution containing Na_2SO_4. On evaporating solutions of $CaCO_3$ in water containing CO_2, and to which various quantities of $CaSO_4$ had been added, calcite only was obtained. The crystals from solutions containing but little $CaSO_4$ were rhombohedra R. As the amount of $CaSO_4$ increased, the form of the crystals changed, $-mR$ appearing, the value of m increasing as more $CaSO_4$ was added. Similar results were got on adding K_2SO_4 instead of $CaSO_4$, the basal plane appearing as well as the form $-mR$. Addition of Na_2SO_4 produced the same results; when added in small quantity no effect could be detected, but as the amount increased, planes of the form $-mR$ appeared, and when much was added, the crystals had the form of prisms terminated by faces of the form R. It has been shown in Part I that the presence of the bicarbonates of K, Na, and Ca has no influence on the form of the crystals deposited, hence the modifications just described are to be attributed to the presence of the SO_4 ion. Moreover the influence of the co-solute seems to be greater the more slowly crystallization takes place.

VIII.—A series of experiments was undertaken to investigate the action of the carbonates and bicarbonates of K and Na on gypsum. The product in all cases was calcite, not aragonite. This is in direct opposition to Becquerel's statement that aragonite can be formed at ordinary temperatures by the action of $NaHCO_3$ on gypsum, and therefore his conclusion, that the presence of $CaCO_3$ as aragonite in gypsum deposits was due to the action of the latter, cannot be maintained. Similar experiments on anhydrite led to the same results, and a discussion of the pseudomorphs of $CaCO_3$ after gypsum and anhydrite, leads the author to the conclusion that 'schaumkalk' is the only authentic instance of aragonite pseudomorphous after gypsum. Hence Rose's statement that aragonite is not formed at temperatures below 30° C. is amply confirmed by the author's researches. A. H.

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Cylindrical Cleavage of Gypsum and Anthophyllite (G. Friedel, Bull. Soc. franç. Min., 1902, vol. xxv, pp. 102–10).—In addition to the perfect cleavage parallel to the plane of symmetry, gypsum is usually stated to possess a fibrous cleavage parallel to the faces of the pyramid $n\{\bar{1}11\}$, and a conchoidal cleavage parallel to the orthopinacoid $a\{100\}$. On the goniometer, however, the fibrous cleavage gives a perfectly continuous band of reflected images in the zone $[\bar{1}11, 1\bar{1}1]=[101]$, with only slightly brighter portions corresponding to the positions of the planes $(\bar{1}11)$ and $(1\bar{1}1)$. There are thus no plane cleavages parallel to these faces, but, on the other hand, a linear or, more correctly, a cylindrical cleavage parallel to the zone-axis [101], this being a direction of maximum cohesion and reticular density in the crystal. The conchoidal cleavage of gypsum is also not a plane cleavage, but a cylindrical cleavage parallel to the zone-axis [001], though less perfectly developed than the cylindrical cleavage parallel to [101].

In the same way anthophyllite possesses a prominent cylindrical cleavage parallel to the prism-edge [001], and only traces of plane cleavages parallel to the faces of the prism $m\{110\}$ and brachypinacoid $b\{010\}$. L. J. S.

Production of Iceland-spar and Cryolite. The following details are taken from a statement of the mineral productions of Denmark and its possessions for the year 1900 (N. V. Ussing, Danmarks geol. Unders., 1902, ser. 2, No. 12, 118 pages and map).

Iceland-spar. The celebrated quarry[1] is situated in a vein of basalt close to the farm Helgustaðir, and about an hour's ride from the trading station of Eskifjörðr on Reydarfjörðr, on the east coast of Iceland. Since 1895 it has been leased by the Government of the island to T. E. Tulinius of Copenhagen. In recent years a large proportion of the calcite taken out has not been of sufficient transparency for optical purposes, and this has caused a considerable rise in price, which for the best quality amounts to £12 per kilogram. About ten men are employed at the quarry during the summer months, and the annual yield is valued at rather over £280.

Cryolite. The quarry at Ivigtut, on the west coast of Greenland, in lat. 63° 13′ N., is in a mass of cryolite, measuring 500 by 100 feet, which occurs embedded in gneiss. The cryolite usually contains 10 to 30 per cent. of impurities, mainly chalybite.

In 1901 the output amounted to 8,125 metric tons. The total yield

[1] Compare this Magazine, 1890, vol. ix, p. 179.

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since 1854 amounts to 307,730 metric tons. The mineral is shipped to Philadelphia and to Copenhagen, and used in the manufacture of opal-glass, enamelled iron, and aluminium. L. J. S.

Epidote crystals from Alaska (Charles Palache, Proc. Amer. Acad. Arts and Sci., 1902, vol. xxxvii, pp. 531–5; and Zeits. Kryst. Min., 1902, vol. xxxvi, pp. 433–7).—Epidote crystals of large size and unusual habit have been found in association with copper-ore in metamorphosed limestone in Prince of Wales Island, Alaska. They are of a dark green to greenish-black colour, but oil-green and translucent in thin crystals. The larger crystals have the form of nearly square tables, flattened parallel to the orthopinacoid, and measure as much as 5½ cm. along the sides and 3 cm. in thickness. In smaller crystals this tabular habit is less pronounced, and these sometimes assume the ordinary prismatic habit of epidote parallel to the axis of symmetry. The crystals are often aggregated in groups of large size, and on them are implanted small, clear crystals of quartz. A detailed crystallographic description, illustrated by a plate of eight figures, is given; twenty-six forms are noted, of which $O\{544\}$ and $j\{755\}$ are new. The crystals are nearly always twinned on the orthopinacoid, and although they often show no re-entrant angles the twinning is readily recognized by the reversal in the direction of the striations on the faces of the clinopinacoid. L. J. S.

The Mica Deposits of India (T. H. Holland, Mem. Geol. Survey, India, 1902, vol. xxxiv, pp. 11–121, with 9 plates).—An interesting account of Indian mica is given under the following main headings:—mineralogical and chemical characters; geological occurrences; geographical distribution; uses; mining practice. The general summary of the mineralogical characters includes new observations on the percussion- and pressure-figures of muscovite. The rays of the pressure-figure intersect at angles of 60°, but the rays of the percussion-figure intersect at angles of 63° and 54°; the principal ray of the latter (which is parallel to the plane of symmetry, and perpendicular to the optic axial plane and one of the rays of the pressure-figure) being inclined to the adjacent rays at 63°. These figures, together with etched figures artificially produced on the cleavage planes, indicate that muscovite is monoclinic, though it may actually be triclinic (as is the case with some other micas) and twinned. The pressure-figure produced at a temperature of about 300° C. has rays intersecting at angles of more nearly 60° (observed 57°, instead of 54° at

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ordinary temperatures), and naturally produced pressure- and percussion-figures surrounding enclosures have rays at 30°. It is possible, therefore, that at a higher temperature mica may have a still higher degree of symmetry.

The mica mined in India is practically all muscovite. It occurs in veins of coarsely crystallized pegmatite penetrating the Archaean schists (mainly mica-schists) of the peninsula of India. Owing to the stability of this region and its long freedom from earth-movements, the large crystals of mica have remained unbroken. The principal mining districts are those of Hazáribágh in Bengal, and of Nellore in Madras, but several other localities are noticed. In the Inikúrti mine, Nellore, 'books' of mica measuring 10 feet across the basal planes and up to 15 feet across the folia have been found; rectangular sheets free from cracks and flaws and measuring 30 × 24 inches have frequently been obtained. Bengal mica has usually a ruby tint, while that from Nellore is more often greenish. The output of 131 mines in 1900 amounted to 916 tons. The primitive and wasteful methods of mining are severely criticized, and improvements suggested. L. J. S.

Senaite and Native Zirconia from Brazil (E. Hussak and J. Reitinger, Zeits. Kryst. Min., 1903, vol. xxxvii, pp. 566–579).—Since the publication of the original description of senaite (Min. Mag., vol. xii, p. 30), this mineral has been found to be widely distributed in the diamantiferous sands of the neighbourhood of Diamantina. The following analyses of unaltered crystals give the new formula $(Fe,Mn,Pb,Mg)O.TiO_2$. Senaite is thus isomorphous with pyrophanite, geikielite, and ilmenite.

TiO_2	FeO	MnO	PbO	MgO	ZrO_2	Sp. gr.
52·11	26·97	10·42	10·86	0·32	trace	5 204
50·32	21·99	17·58	9·62	—	0·84	—

Small, brownish or greyish pebbles (the so-called favas) found in the streams of the augite-syenite district of Serra de Caldas, Minas Geraes, consist largely of compact zirconia (ZrO_2, 81·75–93·18 per cent.). It is suggested that this is an alteration product of the zircon present in the augite-syenite. At the same place there also occurs on the weathered syenite a crust with a radially fibrous structure and smooth, shining surface. This has sp. gr. 5·538, and contains ZrO_2, 97·19 per cent.; the optical characters suggest that it is a new modification of zirconia, distinct from baddeleyite. L. J. S.

Chemical composition of Dumortierite (W. E. Ford, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, pp. 426–430).—The following analyses of dumor-

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ticrite were made with a view to establishing a formula for the mineral: I, material from Clip, Arizona; II, lavender-coloured material from San Diego Co., California; III, from Harlem, New York.

	SiO_2	Al_2O_3	Fe_2O_3	B_2O_3	H_2O	Total	Sp. gr.
I.	29·86	63·56	0·23	5·26	1·41	100·32	3·319
II.	30·58	61·83	0·36	5·93	2·14	100·84	3·226—3·43
III.	31·24	61·26	0·10	6·14	2·09	100·83	3·211—3·392

Regarding the alumina, boron trioxide, and water as bases, there may be deduced from these analyses the acid $H_{60}Si_7O_{44}$; if the hydrogen of this acid be wholly replaced by aluminium, the formula becomes $Al_{20}Si_7O_{44}$, or, written as a basic orthosilicate $(AlO)_{16}Al_4(SiO_4)_7$. In analysis I, in which the ratio of $B_2O_3 : SiO_2 = 1:7$, the formula approximates very closely to $[AlO]_{16}Al_2B_2(SiO_4)_7$. L. J. S.

Chemical composition of Axinite (W. E. Ford, Amer. Journ. Sci., 1903, ser. 4, vol. xv, pp. 195–201).—The following analyses of axinite were made with a view to establishing a formula for the mineral, previous analyses having led to different results and different interpretations: I, crystals of excellent quality from Bourg d'Oisans, Dauphiné; II, material from Obira, Bungo, Japan.

	SiO_2	B_2O_3	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	H_2O	Total.	Sp. gr.
I.	42·78	6·12	17·67	0·99	6·02	2·99	20·16	2·41	1·40	100·54	3·287
II.	41·80	5·61	17·15	1·11	2·84	10·71	19·51	0·21	1·22	100·16	3·028

The new formula deduced from these analyses is expressed as an orthosilicate, $R''_7R'''_4B_2(SiO_4)_8$; the small amount of water, only expelled at a high temperature, is present as basic hydrogen replacing the bivalent bases. L. J. S.

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VOL. I.

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227	1-2	*For* Danas Neolite from Arendat and Eisanach, *read* Scheerer's Neolite from Arendal and Eisenach.

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146	12	*For* anthenticity, *read* authenticity.

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163	8*	*For* 1880, *read* 1884.
—		To list of publications of Thomas Davies add :—
		Crystallization and the microscope. Quart. Journ. Microsc. Sci., 1864, new ser. vol. iv, pp. 247-58 ; 1865, vol. v, pp. 205-12.
		Crystallised stephanite and argentite in Cornwall. Geol. Mag., 1866, p. 432.
		Senarmontite from Cornwall. Geol. Mag , 1867, p. 192.

VOL. XI.

xix	2*	*For* The Honourable A. J. Strutt, *read* The Hon. Robert John Strutt.

VOL. XII.

xxi	2 and 13	*For* June 20, *read* June 19.
185	13	*For* Macivor, *read* MacIvor.

* From bottom of page.

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VOL. XIII. (See also p. 341.)

Page.	Line.	
xiii	1*	*For* Droylesden, *read* Droylsden.
xvii	16	*After* North of England Institute of Mining and Mechanical Engineers, *add* Transactions.
xix	17	*For* Abhandl naturwiss., *read* Abhandl. naturwiss.
44	27	*For* 60°, *read* about 110° and 30°.
49	3* (f. n.)	*For* Wernieke, *read* Wernicke.
56	6*	*For* $n\{211\}$, *read* $n\{112\}$.
58	5	*For* 42° 24′, *read* 44° 24′. The calculated axial ratio is : $a:c=1:0{\cdot}9827$.
62	2	*For* he, *read* the.
86	14	*For* Concrinite, *read* Cancrinite.
97	6*	*For* 1896, *read* 1897.
101	—	*In* Analysis II *add* MgO, 0·26 ; *for* 99·93, *read* 100·19 (total).
102	24–28	*For the paragraph* :—'The acute bisectrix . . . certainty', *substitute* :— The acute bisectrix does not always appear in the centre of the field, and sometimes deviates from it a few degrees in the plane of the optic axes. But by the use of the method described on p. 104, with an isolated rhomb, this deviation has been proved to be due to the uneven nature of the cleavage-flakes and not to a real inclination of the bisectrix to the normal to the face (001).
105	1* (f. n.)	*For* 2E = 70°–74°, *read* 2E = 78°52′ (Na light).
129	3*	*Dele* d_1 211, 36° 12½′, 37° 0′, 1, Minute ; image bad.

* From bottom of page.

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MINERALOGICAL SOCIETY

(Instituted 3rd February, 1876).

BYE-LAWS.[1]

1. The object of the Mineralogical Society of Great Britain and Ireland, with which the Crystallological Society was amalgamated on 11th December, 1883, shall be to advance the knowledge of Mineralogy, and also of Crystallography and Petrology.

2. The Society shall consist of Ordinary Members and Honorary Members.

Ordinary Members.

3. Every candidate for Ordinary Membership shall be proposed by two Ordinary Members, one, at least, of whom shall have personal knowledge of the candidate.

4. The names of the Candidates shall be communicated to every Ordinary Member by the General Secretary.

5. Elections to Ordinary Membership shall be made by the Council at a meeting held at least four weeks after the names of the Candidates have been so communicated; and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the members present and voting.

6. Ordinary Members shall pay an Entrance Fee of one guinea and an annual subscription of one guinea. Ordinary Members elected on or before November 13th, 1900, shall be entitled to compound for the annual subscription by a single payment of ten guineas: Ordinary Members elected after that date shall be entitled to compound by a single payment of fifteen guineas.

7. Annual Subscriptions shall be due on the first of January of each year, but Members elected after the first of October shall not be required to pay a subscription for the then current year.

[1] Adopted at the Anniversary Meeting, November 13th, 1900.

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8. The name of any Ordinary Member whose subscription is more than two years in arrear shall be brought before the Council, and an intimation that this action has been taken shall be communicated to the Member. After the expiration of at least one year from that date, the Council shall be empowered to erase the name from the List of Members.

Honorary Members.

9. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither Entrance Fee nor Annual Subscription.

10. Every candidate for Honorary Membership shall be proposed by two Members of the Council, and the election shall be by the Council.

11. The names of all candidates proposed for Honorary Membership shall be communicated by the General Secretary to every Member of the Council, and the election shall not take place until the expiration of four weeks after such communication.

Council.

12. The Society shall be governed by a Council, consisting of a President, two Vice-Presidents, a General Secretary, a Foreign Secretary, a Treasurer, an Editor of the Journal, and twelve Ordinary Members.

13. All members of the Society who have served the office of President shall be life-members of the Council.

14. The Council shall be elected annually at the Anniversary Meeting.

15. Four Ordinary Members of Council shall retire annually, and shall not be eligible for re-election until the next Anniversary Meeting.

16. The Council shall prepare a List of Members nominated for election as Officers and Ordinary Members of Council.

17. The election of Council shall be effected by the agency of voting papers containing the List nominated by the Council. They shall be sent by the General Secretary, at least four weeks before the Anniversary Meeting, to every Ordinary Member of the Society, and every such Member shall be entitled to substitute the names of any other Ordinary Members of the Society for those on the List.

18. The voting papers shall be returned by the Members to the General Secretary, and shall be examined at the Anniversary Meeting by two Scrutineers appointed by the Chairman, who shall on their report the result of the election. The voting papers need not be signed.

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19. The Council shall have power to appoint Officers, and to co-opt Ordinary Members of Council, to fill vacancies in the Council caused by death or resignation during the interval between two Anniversary Meetings.

20. Meetings of the Council shall be summoned by order of the President or the Council; at such meetings three shall be a quorum, of whom one shall be either the President, a Vice-President, the Treasurer or the General Secretary.

21. A Report of Council on the work and progress of the Society shall be submitted at each Anniversary Meeting.

Trustees.

22. Two or more Trustees shall be appointed by the Council, and the invested property of the Society shall stand in their names.

23. Composition-fees shall be treated as Capital: a Resolution of the Society at a general meeting, summoned with notice of a proposed disposition of property, shall be sufficient authority to the Trustees to give effect to such disposition; provided that a resolution of the Council shall be sufficient authority for any change of investment.

Meetings.

24. Meetings of the Society shall be summoned from time to time, as may be deemed necessary by the Council, or at the requisition of any ten Members of the Society. One of these meetings in each year shall be termed the Anniversary Meeting.

Journal.

25. The Numbers of the *Mineralogical Magazine and Journal of the Society* shall be issued at such intervals as the Council shall determine, and shall be sent, postage paid, to every Member of the Society.

Auditors and Balance Sheet.

26. Two Ordinary Members of the Society, one of whom is not a Member of the Council, shall be appointed annually by the Council to audit the accounts of the Society.

27. No auditor shall serve for more than three years in succession.

28. The audited Balance-Sheet, after submission to the Council, shall be published in the Journal of the Society as early as possible in every year.

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Expulsion of Members.

29. A majority consisting of three-fourths of the whole Council shall have power to expel a Member from the Society, but a Member who has been expelled shall have a right of appeal to the Society. Notice of such appeal to the Society shall be sent by such Member to the General Secretary within four weeks of the expulsion, and the appeal shall be considered by the Society at the next Anniversary Meeting; a majority of the votes recorded at such Meeting sufficing to confirm or annul the decision of the Council.

Alteration of the Bye-Laws.

30. The Bye-laws may be altered only at an Anniversary Meeting, and only by a majority consisting of three-fourths of the Members present and voting. Notice of changes proposed to be made in the Bye-laws shall be communicated by the General Secretary to every Ordinary Member of the Society at least four weeks before the Anniversary Meeting at which they are to be considered.

Obligation Book.

31. Ordinary Members, by payment of their Entrance Fee, signify their acceptance of any Bye-laws approved by the Society; and every Member of the Society shall sign an Obligation Book.

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LIST OF MEMBERS

(March 20th, 1901).

HONORARY MEMBERS.

M. E. Bertrand, *Paris.*
Dr. A. Brezina, *Vienna.*
Prof. W. C. Brögger, *Christiania.*
Prof. G. J. Brush, *New Haven, U.S.A.*
Prof. E. S. Dana, *New Haven, U.S.A.*
Prof. F. Fouqué, *Paris.*
Prof. P. Groth, *Munich.*
Prof. C. Klein, *Berlin.*
Prof. A. Lacroix, *Paris.*
Prof. V. von Lang, *Vienna.*
M. A. Michel Lévy, *Paris.*
Prof. E. Ludwig, *Vienna.*
M. V. L. Moissenet, *Chaumont.*
Baron A. E. Nordenskiöld, *Stockholm.*
Prof. A. Renard, *Gand.*
Prof. H. Rosenbusch, *Heidelberg.*
Dr. K. J. V. Steenstrup, *Copenhagen.*
Prof. G. Tschermak, *Vienna.*
Prof. F. J. Wiik, *Helsingfors.*
Prof. F. Zirkel, *Leipzig.*

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ORDINARY MEMBERS.[1]

A. Annual Subscribers.

L. Life-Members.

C. Belonged to the Crystallological Society at the time of the amalgamation of the two Societies, December 11th, 1883.

	Date of Election.	
A	Nov. 11, 1890	Adcock, Samuel Robert, Esq. F.C.S. *16 Halseley Road, St. Helens, Lancashire.*
L	May 8, 1888	Arnold-Bemrose, Henry Howe, Esq. M.A. F.G.S. *56 Friar Gate, Derby.*
A	Dec. 14, 1881	Baker, Harry, Esq. F.C.S. *Epworth House, Maughland Lane, Runcorn, Cheshire.*
L	Nov. 20, 1894	Barlow, William, Esq. F.G.S. F.C.S. *The Red House, Stanmore, Middlesex.*
L	Feb. 3, 1876	Barnett, A. K., Esq. F.G.S. *11 Penrose Terrace, Penzance, Cornwall.*
L	Jan. 17, 1893	Barrow, George, Esq. F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
L	Feb. 2, 1897	Beale, William Phipson, Esq. K.C. F.G.S. F.C.S. *25 Sheffield Terrace, Kensington, London, W.*
A	Feb. 6, 1894	Beringer, John J., Esq. A.R.S.M. F.C.S. *School of Mines, Camborne, Cornwall.*
A	Nov. 20, 1894	Berkeley, The Rt. Hon. the Earl of, F.G.S. F.C.S. *Foxcombe, Boar's Hill, near Abingdon, Berks.*
L	Feb. 3, 1876	Bonney, The Rev. Prof. Thomas George, D.Sc. LL.D. F.R.S. *23 Denning Road, Hampstead, London, N.W.*
L	April 6, 1897	Bowman, Herbert Lister, Esq. M.A. F.C.S. *Mineral Department, The Museum, Oxford.*

[1] Corrections for this List should be sent to the General Secretary, 36 Woodville Road, Ealing, London, W.

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	Date of Election.	
L	Dec. 18, 1876	Brown, Prof. Alexander Crum, M.D. D.Sc. F.R.S. *8 Belgrave Terrace, Edinburgh.*
L	June 25, 1885	Butler, Francis Henry, Esq. M.A. A.R.S.M. *158 Brompton Road, London, S.W.*
A	May 7, 1889	Butler, William Waters, Esq. F.C.S. *Southfield, Norfolk Road, Edgbaston, Birmingham.*
A	April 4, 1887	Chester, Albert Huntington, Esq. E.M. Ph.D. Sc.D. Professor of Mineralogy. *Rutgers College, New Brunswick, New Jersey, U.S.A.*
A	Feb. 3, 1876	Church, Professor Arthur Herbert, M.A. F.R.S. *Shelsley, Ennerdale Road, Kew, Surrey.*
A	May 8, 1888	Cole, Grenville A. J., Esq. M.R.I.A. F.G.S. Professor of Geology. *Royal College of Science, Dublin.*
L	April 12, 1892	Collins, Henry F., Esq. A.R.S.M. *14 Broad Street Avenue, London, E.C.*
L	Feb. 3, 1876	Collins, Joseph Henry, Esq. F.G.S. *14 Broad Street Avenue, London, E.C.*
L	April 3, 1900	Coomára-Swámy, Ananda K., Esq. B.Sc. F.L.S. F.G.S. *Walden, Worplesdon, near Guildford, Surrey.*
L	May 8, 1888	Crookes, Sir William, F.R.S. *7 Kensington Park Gardens, London, W.*
A	Jan. 31, 1899	Cullis, Charles Gilbert, Esq, D.Sc. F.G.S. Assistant-Professor in Mineralogy. *Royal College of Science, South Kensington, S.W.*
L	Jan. 31, 1899	Currie, James, Esq. M.A. F.R.S.E. *Larkfield, Golden Acre, Edinburgh.*
L	Feb. 3, 1876	Danby, Thomas William, Esq. M.A. F.G.S. *The Crouch, Seaford, Sussex.*
L	Oct. 20, 1885	Daw, John, Esq. Junr. *Brooklands, Rosemont Road, Acton, London, W.*
L	Nov. 15, 1898	De Castro, J. Paul, Esq. M.A. F.C.S. A.I.C. *School of Mines, Redruth, Cornwall.*
A	Nov. 15, 1898	Dickson, Hamilton Charles, Esq.
L	April 14, 1891	Evans, John William, Esq. LL.B. D.Sc. F.G.S. *Care of R. C. T. Evans, Esq. 9 Heathcote Street, London, W.C.*
L	Nov. 18, 1900	Fleischmann, Friedrich Noel Ashcroft, Esq. F.C.S, *6 Collingham Gardens, London, S.W.*

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	Date of Election.	
L	C	Fletcher, Lazarus, Esq. M.A. F.R.S. Keeper of Minerals in the British Museum (Natural History), Cromwell Road, London, S.W. *36 Woodville Road, Ealing, London, W.*
L	Nov. 19, 1895	Fletcher, The Rev. Mark, M.A. F.G.S. Demonstrator in Mineralogy in the Durham College of Science. *Cramlington, R.S.O., Northumberland.*
L	Feb. 3, 1876	Foster, Clement Le Neve, Esq. D.Sc. B.A. F.R.S. H.M. Inspector of Metalliferous Mines for North Wales, etc. and Professor of Mining in the Royal College of Science, South Kensington, London, S.W. *Llandudno, North Wales.*
A	Feb. 3, 1876	Geikie, Sir Archibald, D.Sc. D.C.L. LL.D. F.R.S. Formerly Director-General of the Geological Surveys of the United Kingdom. *The Museum, 28 Jermyn Street, London, S.W.*
A	Feb. 3, 1876	Geikie, James, Esq. LL.D. D.C.L. F.R.S. Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*
L	Feb. 15, 1881	Gibb, T. J., Esq. *37 Old Jewry, London, E.C.*
L	May 10, 1886	Goldschmidt, Dr. Victor, Professor of Mineralogy in the University of Heidelberg. *9 Gaisbergstrasse, Heidelberg, Germany.*
A	April 2, 1895	Gordon, The Rev. John More, F.G.S. *St. John's Vicarage, Redhill, Surrey.*
L	April 12, 1892	Gregory, John Walter, Esq. D.Sc. F.G.S. Professor of Geology. *The University, Melbourne, Victoria, Australia.*
A	C	Gurney, The Rev. Henry Palin, D.C.L. M.A. F.G.S. Principal of the Durham College of Science, Newcastle-on-Tyne. *Roseworth, Gosforth, Newcastle-on-Tyne.*
A	Jan. 23, 1900	Hall, Arthur Lewis, Esq. B.A. F.G.S. *Dulwich College, Dulwich.*
A	Mar. 10, 1885	Harker, Alfred, Esq. M.A. F.G.S. Fellow of St. John's College, Cambridge: Geological Survey of Scotland. *St. John's College, Cambridge.*
A	Feb. 1, 1898	Hartley, Ernald George Justinian, Esq. B.A. F.C.S. *Apedale Hall, Newcastle-under-Lyme, Staffordshire.*

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	Date of Election.	
L	Jan. 23, 1900	Hartley, Harold Brewer, Esq. B.A. F.C.S. *Balliol College, Oxford.*
A	June 3, 1879	Henson, Samuel, Esq. *97 Regent Street, London, W.*
A	May 8, 1888	Hoffmann, G. Christian, Esq. LL.D. Geological Survey of Canada. *Sussex Street, Ottawa, Canada.*
L	Nov. 17, 1896	Holland, Thomas H., Esq. A.R.C.S. F.G.S. *Geological Survey Office, Calcutta, India.*
A	Jan. 7, 1879	Horne, John, Esq. F.R.S. Geological Survey of Scotland. *Geological Survey Office, Sheriff's Court Buildings, Edinburgh.*
A	Feb. 3, 1876	Hudleston, Wilfrid Hudleston, Esq. M.A. F.R.S. *8 Stanhope Gardens, South Kensington, London, S.W.*
A	April 14, 1878	Hughes, Thomas M^{c}Kenny, Esq. M.A. F.R.S. Professor of Geology in the University of Cambridge. *18 Hills Road, Cambridge.*
A	April 18, 1893	Hussak, Dr. Eugen. *Commissão Geographica e Geologica de S. Paulo, S. Paulo, Brazil.*
L	Jan. 14, 1890	Hutchinson, Arthur, Esq. M.A. Ph.D. F.C.S. Demonstrator of Mineralogy in the University of Cambridge. *Pembroke College, Cambridge.*
A	Nov. 14, 1899	Jackson, Henry, Esq. B.A. B.Sc. F.C.S. *Downing College, Cambridge.*
L	April 3, 1884	Judd, John Wesley, Esq. C.B. LL.D. F.R.S. Professor of Geology in, and Dean of, the Royal College of Science, South Kensington, S.W. *16 Cumberland Road, Kew, Surrey.*
L	Feb. 3, 1876	Kinch, Edward, Esq. F.C.S. Professor of Chemistry. *Royal Agricultural College, Cirencester.*
L	Feb. 3, 1876	Kitto, Benedict, Esq. F.I.C. F.G.S. *26 Lancaster Road, Finsbury Park, London, N.*
A	Oct. 20, 1885	Kunz, George Frederick, Esq. M.A. *Care of Messrs. Tiffany & Co., Union Square, New York City, U.S.A.*
A	C	Lewis, William James, Esq. M.A. F.C.S. Professor of Mineralogy in the University of Cambridge. *The New Museums, Cambridge.*
A	May 10, 1886	Lindsey, C. R., Esq. B.Sc. *509 Edge Lane, Droylesden, Manchester.*

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	Date of Election.	
L	C	Liveing, George Downing, Esq. M.A. F.R.S. Professor of Chemistry in the University of Cambridge. *Newnham, Cambridge.*
L	Sept. 6, 1876	Liversidge, Archibald, Esq. M.A. LL.D. F.R.S. Professor of Chemistry. *The University, Sydney, New South Wales.*
A	Oct. 21, 1879	Louis, Henry, Esq. M.A. A.R.S.M. F.G.S. Professor of Mining. *Durham College of Science, Newcastle-on-Tyne.*
L	Sept. 2, 1881	Mallet, Frederick Richard, Esq. F.G.S. F.C.S. *18 The Common, Ealing, London, W.*
L	Dec. 12, 1882	McMahon, Lieut.-General Charles Alexander, F.R.S. *20 Nevern Square, South Kensington, London, S.W.*
L	Feb. 3, 1876	Merry, J. S., Esq. *Swansea, South Wales.*
L	C	Miers, Henry Alexander, Esq. M.A. D.Sc. F.R.S. Professor of Mineralogy in the University of Oxford. *Maydalen College, Oxford.*
A	Feb. 19, 1878	Milne, Prof. John, F.R.S. *Shide Hill House, Shide, Newport, Isle of Wight.*
A	May 10, 1886	Moberg, Dr. Bergrath K. Ad. *Helsingfors, Finland.*
L	Feb. 3, 1876	Morris, James, Esq. *6 Windsor Street, Swansea, South Wales.*
A	C	Müller, Hugo, Esq. Ph.D. F.R.S. *13 Park Square East, Regent's Park, London, N.W.*
L	April 5, 1880	Pearce, Richard, Esq. F.G.S. *Denver City, Colorado, U.S.A.*
A	Feb. 15, 1881	Platnauer, Henry Maurice, Esq. B.Sc. A.R.S.M. F.G.S. *The Museum, York.*
L	June 20, 1899	Pollard, William, Esq. M.A. Ph.D. F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*
A	Nov. 10, 1891	Pope, William Jackson, Esq. F.C.S. *Goldsmiths' Institute, New Cross, London, S.E.*
A	Jan. 11, 1887	Pringle, A., Esq. M.A. B.Sc. Assistant Curator, Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
L	Jan. 11, 1887	Prior, George Thurland, Esq. M.A. F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

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	Date of Election.	
A	Nov. 11, 1890	Rich, W. Esq. *Trevu, Camborne, Cornwall.*
A	Feb. 3, 1876	Rudler, Frederick William, Esq. F.G.S. Curator of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
A	May 8, 1888	Rutley, Frank, Esq. F.G.S. *59 Perham Road, West Kensington, London, W.*
L	Feb. 3, 1876	Scott, Robert Henry, Esq. M.A. D.Sc. F.R.S. *6 Elm Park Gardens, London, S.W.*
A	July 3, 1884	Seligmann, Gustav, Esq. *18 Schlossrondel, Coblentz, Rhenish Prussia.*
A	June 25, 1889	Siggers, J. G., Esq. *13 Gothic Arcade, Snow Hill, Birmingham.*
L	April 6, 1897	Smith, George Frederick Herbert, Esq. M.A. F.R.A.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	June 17, 1897	Sollas, William Johnson, Esq. D.Sc. LL.D. F.R.S. Professor of Geology in the University of Oxford. *The Museum, Oxford.*
A	C	Solly, Richard Harrison, Esq. M.A. F.G.S. *2 Wollaston Road, Cambridge.*
L	Feb. 3, 1876	Sorby, Henry Clifton, Esq. LL.D. F.R.S. *Broomfield, Sheffield.*
A	Feb. 6, 1894	Spencer, Leonard James, Esq. M.A. F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*
A	Feb. 19, 1878	Spezia, Sig. Giorgio, Professor of Mineralogy. *The University, Turin, Italy.*
A	C	Story-Maskelyne, Prof. Mervin Herbert Nevil, M.A. F.R.S. *Basset Down House, Swindon, Wilts.*
A	Nov. 16, 1897	Strutt, The Hon. Robert John, B.A. *Trinity College, Cambridge.*
A	July 18, 1888	Teall, J. J. Harris, Esq. M.A. F.R.S. Director of the Geological Survey of the United Kingdom and of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*
L	Feb. 15, 1881	Terrill, William, Esq. F.C.S. *42 St. George's Street, Swansea, South Wales.*
L	Aug. 15, 1877	Trechmann, Charles O., Esq. J.P. Ph.D. F.G.S. *Hudworth Tower, Castle Eden, Co. Durham.*
A	April 14, 1891	Tutton, Alfred Edwin, Esq. B.Sc. A.R.C.S. F.R.S. *17 Bardwell Road, Oxford.*

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	Date of Election.	
A	Feb. 3, 1876	Walker, John Francis, Esq. M.A. F.G.S. F.L.S. F.C.S. *45 Bootham, York.*
L	Feb. 6, 1894	Watts, William Whitehead, Esq. M.A. F.G.S. Assistant Professor of Geology, University of Birmingham. *Holmwood, Bracebridge Road, Four Oaks, Sutton Coldfield, Warwickshire.*
L	Nov. 19, 1895	Webb, R. C., Esq. *Kimberley Club, Kimberley, South Africa.*
L	Mar. 19, 1901	Weston, Digby St. A. P., Esq. Lieutenant R.N., H.M.S. "Diana," Mediterranean Squadron. *Greenfields, East Sheen, London, S.W.*
L	Feb. 3, 1876	Wills, J. Lainson, Esq. F.C.S. *Care of Dr. F. Wyatt, 39 South William Street, New York City, U.S.A.*
L	June 28, 1896	Wills, Louis, Esq. *29 Cornhill, London, E.C.*
L	June 3, 1882	Wiltshire, The Rev. Thomas, M.A. D.Sc. F.G.S. F.L.S. F.R.A.S. Professor Emeritus, King's College, London. *25 Granville Park, Lewisham, London, S.E.*
A	Feb. 18, 1889	Woodward, Bernard Henry, Esq. F.G.S. *The Museum, Perth, Western Australia.*
L	C	Woodward, Charles J., Esq. B.Sc. F.G.S. Birmingham Municipal Technical School. *97 Harborne Road, Birmingham.*
A	June 17, 1897	Woollett, N. E., Esq. *Wingham, Dover, Kent.*

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LIST OF SERIALS IN THE LIBRARY.

(March, 1901).

Librarian: Prof. W. J. Lewis, The New Museums, Cambridge.

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Bristol Naturalists' Society, Proceedings	From Vol. III, 1880 to VI, 1891	—
Cornwall, Royal Institution, Journal	IX, 1886 to XIII (4), 1898	Part 37, 1891; Part 39, 1893
Edinburgh Geological Society, Transactions	VII, 1894–9	—
Glasgow Geological Society, Transactions	X, 1892–6	—
Mineralogical Magazine (2 copies), I, 1876 to XII, 1900	—	—
Naturalist, The	1885 to 1899	Nos. 139, 142, 1887
North of England Institute of Mining and Mechanical Engineers	XXVI, 1876 to XLIX, 1900	—
Yorkshire Naturalists' Union, Transactions	I, 1878 to XXI, 1898	IX to XIX
Australian Museum (Sydney), Records	I, 9, 1891 to III, 7, 1900	—
Australian Museum (Sydney), Reports	1882 to 1899	—
New South Wales, Royal Society, Journal and Proceedings	IX, 1875 to XXXIII, 1899	XIII, 1879; XIV, 1883; XVII, 1887
New South Wales, Department of Mines, Annual Reports	1876 to 1899	1878, 9; 1882, 3; 1885; 1887–9; 1897
New South Wales, Mines and Mineral Statistics	1875 to 1880	—
New South Wales, Geological Survey, Records	II, 1890 to VI, 1900	—
New South Wales, Geological Survey, Memoirs	Nos. 1 to 9	No. 6
New South Wales, Technological Museum, Reports	1883 to 1890	1887
Victoria, Mineral Statistics	1876 to 1881	—
Victoria, Reports of Chief Inspector of Mines	1874, 5; 1881	—
Victoria, Reports of Mining Surveyors	March 1875 to Sept. 1882	—
New Zealand, Geological Survey, Reports, 1874 to 1878	—	—
Canada, Geological Survey, Reports, 1894 to 1897	1879 to 1893	—

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BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Nova Scotian Institute Nat. Sci., Proceedings and Transactions	IV, 4, 1877 to X, 1, 1899	V, 2 and 4; VI; VII, 1, 2
American Chemical Journal, II, 1880 to XXII, 1899	I, 1879	--
American Geologist, XVII, 1896 to XXVI, 1900	—	--
American Journal of Science, XIII [iii] 1877 to X [iv], 1900	—	—
Journal of Geology, V, 1897 to VIII, 1900	—	—
California, Annual Reports of the State Mineralogist	IV, 1884 to XIII, 1896	—
Colorado Scientific Society, Proceedings	I, 1883 to III, 1889	II, 1; III, 1
New York Academy of Sciences, Annals	1881–3	—
New York Academy of Sciences, Transactions	1881–3	—
Philadelphia Academy of Natural Sciences, Proceedings, 1877 to 1884	—	1881; 1883
Smithsonian Institution, Annual Reports, 1881 to 1895	—	—
United States Geological Survey, Annual Reports, II, 1880 to XX, 1899	—	—
United States Geological Survey, Bulletins, I, 1883 to CLX, 1899	CLXI, CLXII, 1899	VII–XIV, XLVI, part of LXV
United States Geological Survey, Mineral Resources, 1883 to 1893	—	—
United States Geological Survey, Monographs, I, 1890 to XXXVIII, 1899	—	—
United States Geological and Geographical Survey, for 1878 (Wyoming and Idaho), 1883	—	—
France, Société Minéralogique, Bulletin, I, 1878 to XXII, 1899	—	—
Luxembourg, Publications Institut Grand-ducal (Soc. Sci. Nat.)	II, 1854 to XXIV, 1896	VI, 1863; XXI, XXII, 1892–3
Belgique, Société Géologique, Annales, I, 1874 to XXVII, 1900	—	—
Giornale di Mineralogia (Sansoni), I, 1890 to IV, 1893	V, 1894	Fasc. III, 1894
Rivista di Mineralogia e Crist. (Panebianco), XVII, 1897 to XXV, 1900	—	—
Il Nuovo Cimento, I [iv] 1895 to XI [iv] 1900	III, IV [iv], 1896	III, 2, 1896

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BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Atti R. Accad. Lincei, Rendiconti, I, 1885 to VI, 2, 1890	IV, 2	—
Atti R. Accad. Lincei, Transunti, VII, 1883 to VIII, 1884	V, 1881	Index to Vol. V; VI, 1882
Atti Soc. Toscana Sci. Nat., Memorie, III, 1877 to XVI, 1899	XVII, 1900	—
Reale Comitato Geologico d'Italia, Bollettino, VIII, 1877 to XXX, 1899	—	—
Rendic. Accad. Sci. Napoli, III, 1889 to VIII, 1894; I [iii], 1895	II, 1888; IV, 1890; II [iii], 1890 to VI [iii], 1900	II [ii], 3 to 8; IV [ii], 5; V [iii], 5
Mineralogische und Petrographische Mittheilungen, I, 1878 to XIX, 1899	—	—
Sitzungsber. u. Abhandl naturwiss. Ges. Isis, Dresden	1892, 2 to 1899, 1	1897, 1
Vienna, Geolog. Reichsanstalt, Jahrbuch, XXVII, 1877 to XLIX, 1899	L, i, 1900	—
Vienna, Geolog. Reichsanstalt, Verhandlungen	1877 to 1900	—
Vienna, Naturhist. Hofmuseum, Annalen, I, 1886 to XI, 1896	—	—
Zeitschrift f. Krystallographie und Mineralogie, I, 1877 to XXXIII, 1900. Rep. XI to XX; XXI to XXX	—	—
Zeitschrift f. Naturwissenschaften, Halle, XLIX, 1877 to LXVI, 1893	LVI, 1883; LXVII, 1894 to LXXI, 1898	LVI, 6; LXVIII, 3, 4; LXIX, 3–6
Finland, Commission Géologique, Bulletin	I, 1895 to VIII, 1898; XI, 1900	—
Finland, Geol. Undersökning, Beskrifning till Kartbladet, X to XVII	I; II; XXII to XXIX; XXXV	VI–VIII, XVIII–XXI, XXXII, XXXIII
Upsala, Geological Inst. Univ., Bulletin, I, 1893–4 to III, 1897	IV, 1900	—
Upsala, Univ. Min.-Geol. Instit., Meddelanden, I to XV	XVI to XXV	IV, XIV, XXIII, XXIV
Grönland, Meddelelser om, I, 1879 to XX, 1898	XXI, XXIII, 1899	XXII, 1899
Mexico, Memorias y Revista Soc. Cient. "Antonio Alzate"	I, 1887 to III, 1890	I, pp. 363 to 418; II, 1889
S. Paulo, Bol. Com. Geog. e Geol. I, 1889 to XIV, 1897	—	—
S. Paulo, Bol. Com. Geog. e Geol., Dados Climat., 1887 to 1892	1893 to 1897	—
Argentina, Anales Soc. Cient., VIII, 1879 to L, 1900	XXIX, XXX	XXIX, 2

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PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 22nd, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Secretary reported that the nomination of Lieutenant D. St. A. P. Weston, R.N., for the Membership of the Society had been communicated to the Members.

The resignation of Mr. Boulger and the death of Mr. Taylor, Ordinary Members, were announced.

The President, the General Secretary, the Editor of the Journal, Dr. Hugo Müller and Professor Miers were appointed to serve on the Editorial Committee of the Journal.

Messrs. Collins and Kitto were elected auditors for the accounts of the Society for the years 1900 and 1901.

The audited Balance Sheet for the year ending December 31st, 1900, was submitted and approved.

Resolved to issue a List of Members and the Bye-Laws as part of each volume of the Journal.

The President generously offered to present certain volumes of the Bulletin of the French Mineralogical Society; and also to present the sum of ten pounds to the Society for use in the binding of the books in the Library: a vote of thanks was passed to the President for these gifts.

The President further presented a beautifully bound book with blank leaves of linen-made paper for use as an Obligation-Book: a vote of thanks for this was passed.

The date of next Meeting was changed from April 2nd to March 19th.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 22nd, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Nineteen Members and one Visitor were present.

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The following papers were read :—

1. Note on an occurrence of Mirabilite : by Dr. C. O. Trechmann (p. 73).

2. On a question relative to extinction-angles in rock-slices : by Mr. A. Harker (p. 66).

3. A new device for separating minerals by heavy liquids : by Mr. Harold B. Hartley.

4. On the arrangement of the chemical atoms in calc-spar and in some other crystals : by Mr. W. Barlow.

5. Addition to a former note on the rotation of points and planes : by Mr. R. W. H. T. Hudson. (Communicated by Professor Lewis.) (p. 71).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 19th, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Lieutenant D. St. A. P. Weston, R.N., was elected an Ordinary Member of the Society.

Reported that Mr. George Abbott, M.R.C.S., and Mr. Herbert Thomas Burls, F.G.S., had been proposed as candidates for the Ordinary Membership of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 19th, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Thirteen Members were present.

The election of Lieutenant D. St. A. P. Weston, R.N., to the Ordinary Membership of the Society was confirmed.

The following papers were read :—

1. Notes on an occurrence of minerals at Haddam Neck, Connecticut, U.S.A. : by Mr. H. L. Bowman.

2. On Calaverite from the Cripple Creek District : by Mr. G. F. Herbert Smith : with chemical analysis by Mr. G. T. Prior.

3. On the arrangement of the chemical atoms in Boracite and Cassiterite : by Mr. W. Barlow.

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Mineralogical Society—Abstract of Receipts and Payments from 1st January to 31st December, 1900.

RECEIPTS.

	£ s. d.	£ s. d.
Balance from year 1899		92 19 11
Subscriptions:—		
(1) In advance	1 1 0	
(2) Current	42 0 0	
(3) In arrear	5 5 0	
		48 6 0
Entrance Fees and Compositions		47 5 0
Sale of Publications by publishers		25 5 0
Authors' Extra Copies		1 16 5
Dividends on Stock		12 13 9
		£228 6 1

PAYMENTS.

	£ s. d.	£ s. d.
Printing and Stationery		60 6 3
Illustrations		21 11 2
Attendants' Fees at Meetings		1 6 0
Clerk's Fee in charge of Stock (1899)		1 1 0
Postage		2 7 0
Commission on Cheques		0 0 6
Investments and Brokers' Commission		62 13 9
Balance at Bank	£75 8 4	
,, in Office	3 12 1	
		79 0 5
		£228 6 1

Examined and compared with the vouchers and found correct. (Signed)

BENEDICT KITTO,
J. H. COLLINS, } *Auditors.*

LIABILITIES.

	£ s. d.
Printing No. 58 of the Journal	51 9 0
Miscellaneous Printing, including the Bye-Laws and List of Members	6 11 0
Clerk for care of Stock in 1900	1 1 0
Postage	0 17 1
Excess of Assets over Liabilities	585 8 4
	£645 6 5

ASSETS.

	£ s. d.
Balance as above	79 0 5
Subscriptions unpaid	15 15 0
Stock in 2¾ Consols: £526 11s. 1d., valued at 96	505 9 7
Dividend on Stock, January 1901	3 8 9
Sale of Journal, 1900	20 17 5
Arrears of Sales	2 15 3
Authors' Copies	18 0 0
	£645 6 5

The number of Life-Members on December 31st, 1900, was 52.

Memo.—The Stock of Publications and the Value of the Library are not included in the above Assets.

(Signed) F. W. RUDLER,
Treasurer.

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 18, 1901.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

Mr. Herbert Thomas Burls, F.G.S., was elected to the Ordinary Membership of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 18, 1901.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

Fifteen Members were present. The election of Mr. H. T. Burls as an Ordinary Member was confirmed.

The following papers were read:—

1. On the anharmonic ratio of four faces in a zone: by Mr. Alfred Harker.

2. On the arrangement of the chemical atoms in potassium-alum, and in some of the bodies which display tetartohedral symmetry: by Mr. W. Barlow.

3. Remarks on the crystallography of Calaverite: by Mr. G. F. Herbert Smith (p. 122).

4. On pseudomorphous calcium carbonate from the Clyde-bed: by Dr. C. O. Trechmann.

5. On some inter-relations of species, especially sulphates and phosphates: by Mr. G. T. Prior.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 12, 1901.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

The deaths of Baron Nordenskiöld, Honorary Member, Dr. Moberg, and Mr. W. Terrill, Ordinary Members, were announced.

The Foreign Secretary was requested to send a letter of congratulation to Professor Groth on the completion of the twenty-fifth year of the publication of the *Zeitschrift für Krystallographie.*

The following dates were selected for the meetings of the Society during 1902:—February 4, March 25, June 24, and November 18, the last to be the Anniversary Meeting.

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ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 12, 1901.

Professor A. H. CHURCH, M.A., F.R.S., President, in the Chair.

Nineteen Members and one visitor were present.

The scrutineers reported that forty voting papers had been returned, and that the following had been elected Officers and Members of Council for the year 1901–2:—

President. HUGO MÜLLER, ESQ., Ph.D., F.R.S.
Vice-Presidents. PROF. G. D. LIVEING, M.A., F.R.S.
PROF. H. A. MIERS, M.A., F.R.S.
Treasurer. LIEUT.-GEN. C. A. MCMAHON, F.R.S.
General Secretary. L. FLETCHER, ESQ., M.A., F.R.S.
Foreign Secretary. PROF. J. W. JUDD, C.B., F.R.S.
Editor of the Journal. L. J. SPENCER, ESQ., M.A., F.G.S.

Ordinary Members of Council.

J. J. H. TEALL, ESQ., M.A., F.R.S. — J. H. COLLINS, ESQ., F.G.S.
A. E. TUTTON, ESQ., B.Sc., F.R.S. — PROF. W. J. LEWIS, M.A., F.C.S.
PROF. W. W. WATTS, M.A., F.G.S. — W. BARLOW, ESQ., F.G.S.
W. P. BEALE, ESQ., K.C., F.G.S. — B. KITTO, ESQ., F.I.C., F.G.S.
THE EARL OF BERKELEY, F.G.S. — F. W. RUDLER, ESQ., F.G.S.
A. HUTCHINSON, ESQ., M.A., PH.D. — G. F. HERBERT SMITH, ESQ., M.A.

The following Report of Council for the year 1900–1 was read by the General Secretary.

ANNUAL REPORT.

The Balance Sheet for the year ending December 31, 1900, which was issued with Number 59 of the Journal, showed that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £645 6*s.* 5*d.*, and that the Liabilities amounted to £59 18*s.* 1*d.* The number of actual Members, who had compounded before December 31, 1900, for the payment of their Annual Subscription, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £505 9*s.* 7*d.*

During the Session 1900–1 the Society has lost three Ordinary Members and one Honorary Member by death, and two Ordinary Members by resignation; on the other hand, two Ordinary Members

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have been elected. The total number of members is now 121; of these 102 are Ordinary Members and nineteen are Honorary Members.

Four meetings have been held during the year, all in London and (by kind permission) in the apartments of the Geological Society, Burlington House.

Two Numbers of the Journal, No. 58 published in November, 1900, and No. 59 published in May, 1901, have been issued since the last Anniversary Meeting. The papers therein contained differ widely in character. On the instrumental side of crystallographic science, Mr. Herbert Smith has described an improved form of his three-circle goniometer. To the mathematical side of crystallography and optics contributions have been made by Professor Lewis, Mr. Hudson, Mr. Hilton and Mr. Harker. On the physical side, Mr. Bowman has given an account of a method of demonstrating the variation of thermal conductivity with crystallographic direction. To our knowledge of various mineral species additions have been made in papers by Mr. Spencer, on Marshite, Miersite, Iodyrite and Stannite, by Professor Lewis and Mr. Hall on Copper-pyrites, by Mr. Solly on Rathite, by Mr. Bowman on Pyroxene and Sapphire, by Miss Kelly on calcium carbonate. Information relative to topographical mineralogy has been given by Mr. Bowman and Dr. Trechmann. Chemical mineralogy is represented by a paper of Dr. Evans on the alteration of Iron-pyrites by underground water. Petrography is illustrated by two papers of Mr. Prior. Mr. Fletcher has given a detailed report on the circumstances of the fall and on the characters of the meteoric stones of Mount Zomba. Mr. Spencer has supplied a useful list of new Mineral Names and an Index to Volume XII of the Journal.

For the convenience of the Members, the new Bye-Laws, a list of the Members, and a list of the Serials in the Library, have been issued as part of the first Number of the current Volume of the Journal.

The Society is deeply indebted to the President, Professor Church, for the gift of (1) various volumes of the Journal of the Mineralogical Society of France, (2) the sum of ten pounds for expenditure in binding and (3) a beautifully bound Obligation-Book for the preservation of the autographs of the Members.

The Council has to congratulate the Society on its scientific prosperity.

On the motion of the President, seconded by the General Secretary, the Report was adopted. A vote of thanks to the Geological Society for the use of its apartments was carried by acclamation.

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The following papers were then read:—

1. On Baumhauerite, a new mineral, Dufrenoysite and Hyalophane, from the Binnenthal: by Mr. R. H. Solly (p. 151).

2. On Gibbsite from the Palni Hills in Southern India: by Dr. H. Warth (communicated by Mr. Mallet) (p. 172).

3. On the occurrence of Gold in the Klondike: results of a visit in 1901: by Professor Miers.

The papers were illustrated by specimens, and Professor Miers showed a series of lantern-slides prepared from photographs taken by him at Klondike.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, February 4, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Mr. George Duncan McGrigor, F.R.G.S., was elected an Ordinary Member of the Society. The resignation of Mr. H. M. Platnauer, Ordinary Member, was announced.

GENERAL MEETING.

Held in the Apartments of the Geological Society, February 4, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Fifteen members were present. The election of Mr. G. D. McGrigor as an Ordinary Member was confirmed.

The following papers were read:—

1. On the Hornsilvers: by Messrs. G. T. Prior and L. J. Spencer (p. 174).

2. The identity of Kilbrickenite with Geocronite: Analyses of Miersite, Marshite and Copper-pyrites: by Mr. G. T. Prior (p. 186).

3. A new Sapphirine-like mineral from Ceylon: by Messrs. G. T. Prior and A. K. Coomára-Swámy.

4. Attempts to reproduce interference-effects by three-colour printing: by Professor Miers.

Specimens illustrative of the above papers were shown by Mr. Coomára-Swámy and Professor Miers; the latter further exhibited twin-crystals of calcite according to the less common twin-plane (11$\bar{1}$) from a new locality in Somersetshire, and also some crystalline gold-nuggets from Klondike.

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 25, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Mr. Alfred Prentice Young, Ph.D., F.G.S., was elected an Ordinary Member of the Society.

Messrs. Miers and Spencer were asked to report to the Council relative to the presentation and exchange list.

The President, General Secretary, and the Editor, in conjunction with Professor Church and Professor Miers, were appointed Editorial Committee for the Journal.

Mr. Spencer reported that he had indexed the literature relating to Mineralogy and Crystallography published in the United Kingdom during 1901, and had sent, on behalf of the Society, the index-slips to the Central Bureau of the International Catalogue of Scientific Literature.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 25, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Fourteen Members were present. The election of Dr. Young to the Ordinary Membership of the Society was confirmed.

The following paper was read:—

The Petrology of British East Africa: notes on the rock-specimens collected by Professor J. W. Gregory and Sir Harry Johnston respectively: by Mr. G. T. Prior (p. 228).

The paper was illustrated by specimens and micro-sections.

Professor Miers submitted a fragment of a statuette consisting chiefly of green mica: archaeologists agree that the workmanship is Roman, and Professor Miers suggested that the material may be one of the varieties of 'emerald' described by Pliny.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 10, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The resignation of the Treasurership by Lieut.-Gen. McMahon, owing to failing eyesight, was announced. A vote was passed expressing deep sympathy with him in his trouble and high appreciation of the services which have been rendered by him to the Society. Mr. W. P. Beale was

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elected Treasurer, and Lieut.-Gen. McMahon was elected to the Membership of Council thus vacated.

Mr. William B. Giles, F.I.C., was elected an Ordinary Member of the Society. The death of M. Moissenet, Honorary Member, was announced.

The Secretary submitted a list of changes which he recommended to be made in the Bye-laws of the Society.

Professor Judd, Foreign Secretary, was authorized to inform the Mayor of St. Just-en-Chaussée that the Society sympathizes with the project to establish a Memorial to the brothers Haüy in their native place.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 10, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Seventeen Members were present. The election of Mr. W. B. Giles to the Ordinary Membership of the Society was confirmed.

The following papers were read:—

1. On Meigen's method of discriminating Calcite and Aragonite: by Dr. A. Hutchinson.

Experiments had been made in order to discover the cause of the discrepancy in the results obtained by Meigen and Panebianco in the application of Meigen's method of discriminating calcite and aragonite [abstract, this vol., p. 206]. It was found that calcite, when treated with a boiling dilute solution of cobalt nitrate, only remains white or becomes yellow (as stated by Meigen) when the cobalt nitrate contains traces of iron, and that Panebianco's lavender-blue colour is only obtained when the cobalt nitrate is free from iron.

2. On the crystalline forms of Krennerite: by Mr. G. F. Herbert Smith (p. 264).

3. On the Gnomonic Projection: by the same.

4. On Volcanic dust fallen at Barbados: by Mr. G. T. Prior.

Specimens were exhibited, and the mineral constituents described, of the volcanic dust which fell in Barbados on May 7 and 8 after the eruption of the Soufrière of St. Vincent. The fact that the constituents are like those of a hypersthene-augite-andesite connects the eruptions with the Pacific rather than with the Atlantic volcanic chain.

5. On the non-existence of 'Kalgoorlite' and 'Coolgardite' as mineral species: by Mr. L. J. Spencer (p. 268).

6. On the crystalline forms of Liveingite: by Mr. R. H. Solly.

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Mr. G. F. Herbert Smith exhibited and explained the new form of Three-Circle Goniometer constructed by Messrs. Troughton and Simms for the British Museum according to the plans suggested by him.

Specimens were exhibited by Messrs. Hutchinson, Prior, Spencer, and Solly in illustration of their papers.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 18, 1902.

Dr. Hugo Müller, FR.S., President, in the Chair.

The following Candidates were elected Ordinary Members of the Society:—Mr. Herbert Stanley Jevons, M.A., B.Sc., F.G.S.; Mr. Arthur Edward Ian Montagu Russell; Mr. Andrew Gibb Maitland, F.G.S.; Mr. John Smith Flett, M.A., D.Sc., F.R.S.E., F.G.S.; Mr. John Allen Howe, B.Sc., F.G.S.; and Mr. Frederic Philip Mennell, F.G.S. Professor A. D'Achiardi of Pisa was elected an Honorary Member of the Society.

The following dates were selected for the meetings of 1903:—February 3, March 24, June 9, November 17, the last to be the Anniversary Meeting.

Mr. J. H. Collins and Mr. H. L. Bowman were elected Auditors of the Balance Sheet for the year ending Dec. 31, 1902.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 18, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty-four Members and one visitor were present.

The President nominated Mr. Barlow and Mr. Herbert Smith to act as scrutineers of the voting papers for the election of Officers and Council; the scrutineers reported that thirty-seven voting papers had been returned to the General Secretary, and that the List as nominated by the Council for the year 1902–3 was approved, namely:—

President. Hugo Müller, Esq., Ph.D., F.R.S.
Vice-Presidents. Prof. G. D. Liveing, M.A., F.R.S.
Prof. H. A. Miers, M.A., D.Sc., F.R.S.
Treasurer. W. P. Beale, Esq., K.C., F.G.S., F.C.S.
General Secretary. L. Fletcher, Esq., M.A., F.R.S.
Foreign Secretary. Prof. J. W. Judd, C.B., LL.D., F.R.S.
Editor of the Journal. L. J. Spencer, Esq., M.A., F.G.S.

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Ordinary Members of Council.

The Earl of Berkeley, F.G.S.	F. W. Rudler, Esq., F.G.S.
A. Hutchinson, Esq., M.A., Ph.D.	G. F. Herbert Smith, Esq., M.A.
J. H. Collins, Esq., F.G.S.	A. Harker, Esq., M.A., F.R.S.
Prof. W. J. Lewis, M.A., F.C.S.	Lieut.-Gen. C. A. McMahon, F.R.S.
W. Barlow, Esq., F.G.S.	W. Pollard, Esq., M.A., Ph.D.
B. Kitto, Esq., F.I.C., F.G.S.	G. T. Prior, Esq., M.A., F.G.S.

The General Secretary read the following

ANNUAL REPORT OF COUNCIL.

The Balance Sheet for the year ending December 31, 1901, which will be issued with the next Number of the Journal, shows that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £650 8*s.* 9*d.*, and that the Liabilities amounted to £17 0*s.* 1*d.* The number of Life-Members on December 31, 1901, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £519 15*s.* 10*d.*

During the Session 1901–2 the Society has lost two Ordinary Members by resignation, and one Honorary Member by death; on the other hand, three Ordinary Members have been elected, and Professor A. D'Achiardi of Pisa has been added to the list of Honorary Members. The total number of Members is now 121; of these 102 are Ordinary Members and nineteen are Honorary Members.

Four meetings have been held during the year, all in London and (by kind permission) in the Apartments of the Geological Society, Burlington House.

One Number of the Journal, No. 60, published in May 1902, has appeared during the Session.

The Council has to congratulate the Society on its continued prosperity.

On the motion of the President, seconded by Mr. Scott, the Report was adopted. Votes of thanks to the retiring Auditor (Mr. Kitto) and to the Geological Society for the permission to meet in its Apartments were carried with acclamation.

The following alterations in the Bye-laws were proposed by the General Secretary in accordance with Bye-law 30.

Bye-law 4. 'The names of the Candidates shall be communicated to every Ordinary Member by the General Secretary.' To be withdrawn.

Bye-law 11. 'The names of all candidates proposed for Honorary

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Membership shall be communicated by the General Secretary to every Member of the Council, and the election shall not take place until the expiration of four weeks after such communication.' To be withdrawn.

Bye-law 5. The words 'at a meeting held at least four weeks after the names of the Candidates have been so communicated' to be withdrawn.

Bye-law 10. The words 'and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the members present and voting,' to be added at the end of the Bye-law.

The proposal was carried.

The elections of Mr. H. S. Jevons, Mr. Arthur Russell, Mr. A. G. Maitland, Dr. J. S. Flett, Mr. J. A. Howe, and Mr. F. P. Mennell, to the Ordinary Membership of the Society were confirmed.

The President called the attention of the Meeting to the Memorial proposed to be erected to the brothers Haüy in their native place.

The following papers were then read:—

1. The crystalline forms of Proustite: by Mr. F. E. E. Lamplough (communicated by Professor Lewis) (p. 294).

2. On some minerals from Switzerland: by Professor W. J. Lewis (p. 291).

3. On Baumhauerite, Seligmannite, and a third mineral from Binn: by Mr. R. H. Solly.

4. On a Gnomonic Protractor: by Mr. G. F. Herbert Smith.

5. On the Molecular Volumes of some crystallographically similar minerals: by Mr. G. T. Prior (p. 217).

Owing to the lateness of the hour the following papers were taken as read:—

6. On Phonolitic Rocks from St. Helena and Ascension: by Mr. G. T. Prior (p. 256).

7. Crystalline forms of Carbides and Silicides of iron and manganese ('Ferro-manganese,' &c.): by Mr. L. J. Spencer (p. 296).

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MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1901.

Receipts.	£ s. d.	£ s. d.
Balance from the year 1900		79 0 5
Subscriptions—(1) current	30 8 9	
(2) arrears	16 16 0	
		47 4 9
Entrance fees and compositions		17 17 0
Sale of publications by publishers	20 17 5	
,, from Stock (from 1898 inclusive)	4 17 1	
Miscellaneous receipts by Clerk in charge of Stock	2 11	
		25 17 5
Authors' extra copies		20 8 9
Donation from Professor Church for binding		10 0 0
Dividends on Stock		18 16 8
		£214 5 0

Payments.	£ s. d.	£ s. d.
Printing and Stationery		105 7 7
Illustrations		4 7 0
Binding		10 7 8
Attendant's Fee at Meetings		10 0
Clerk's Fee in charge of Stock (1900 & 1901)		2 2 0
Postage and Parcels		1 2 5
Commission on Cheques		1 0
Cover for Obligation Book	5 0	
Slips for Catalogue, Royal Society	3 2	
		8 2
Investments and Brokers' Commission		18 16 8
Balance at Bank	70 11 6	
,, in Office	5 11 5	
		76 2 11
		£214 5 0

Examined and compared with the vouchers, and found correct.

(*Signed*) BENEDICT KITTO } Auditors.
J. H. COLLINS }

Liabilities.	£ s. d.	£ s. d.
Debts owing—Printing	4 13 6	
Illustrations	6 3	
		4 19 9
Honorarium owing to Editor		10 10 0
Secretarial postage to Dec. 31, 1901		1 0 4
Attendant's Fee at Meetings to Dec. 31, 1901		10 0
Excess of assets over liabilities		633 8 8
		£650 8 9

Assets.	£ s. d.
Balance as above	76 2 11
Subscriptions unpaid	13 13 0
Stock in Consols £540 18*s.* 7*d.*, valued at £96	519 15 10
Dividend, January, 1902	8 10 0
Balance owing from Publishers from sale of Journal, 1901	37 7 0
	£650 8 9

The number of Life Members on December 31, 1901, was 52.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE,
Hon. Treasurer.

June 30, 1902.

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, February 3, 1903.

Prof. H. A. Miers, F.R.S., Vice-President, in the Chair.

The deaths of the Reverend Professor T. Wiltshire, Ordinary Member, and Professor A. D'Achiardi, Honorary Member, were announced.

Professor Theodor Liebisch, of Göttingen, and Professor Giovanni Strüver, of Rome, were elected Honorary Members of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, February 3, 1903.

Prof. H. A. Miers, F.R.S., Vice-President, in the Chair.

Eleven Members were present. The elections of Professor Liebisch, of Göttingen, and of Professor Strüver, of Rome, to the Honorary Membership were confirmed.

The following papers were read:—

1. On a meteoric stone seen to fall on August 22, 1902, at Caratash, Smyrna: by Mr. L. Fletcher, F.R.S.

2. Note on the history of the mass of meteoric iron found in the neighbourhood of Caperr, Patagonia: by Mr. L. Fletcher, F.R.S.

3. On the crystalline forms of carbides and silicides of iron and manganese: by Mr. L. J. Spencer (p. 296).

4. The refractive indices of Pyromorphite: by Mr. H. L. Bowman (p. 324).

5. Note on Quartz crystals from De Aar: by Mr. T. V. Barker (communicated by Professor Miers) (p. 331).

Professor Maskelyne exhibited some specimens of worked flint implements from Knowle, Wiltshire, having a smooth polish of doubtful origin: also some lustrous black mountain-limestone from Brecon.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 24, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Mr. John Brooke Scrivenor, M.A., F.G.S., of the Geological Survey, was elected an Ordinary Member of the Society.

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GENERAL MEETING.

Held in the Apartments of the Geological Society, March 24, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Nineteen Members were present. The election of Mr. J. B. Scrivenor to the Ordinary Membership of the Society was confirmed.

The following papers were read:—

1. On the Diathermancy of Antimonite: by Dr. A. Hutchinson (p. 342).

2. A peculiar form of Magnetite in Bunter Sandstone: by Mr. J. B. Scrivenor (p. 351).

3. Anatase in the Trias of the Midlands: by Mr. J. B. Scrivenor (p. 348).

4. A large crystal of Sulpharsenite of Lead from the Binnenthal: by Professor W. J. Lewis.

A large, isolated crystal, measuring 4 × 1 × ¼ inch, was shown. The following analysis by Mr. H. Jackson proves it to be sartorite:—Pb, 42·93; S, 25·82; As, 31·11.

5. A twin of Copper-pyrites: by Professor W. J. Lewis.

6. A mineral from the mines of the Borax Consolidated Co., California: by Mr. W. B. Giles (p. 353).

Mr. J. A. Howe exhibited a peculiar stalactite of calcite, and made a suggestion as to the mode of formation.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 9, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The audited Balance Sheet for the year ending December 31, 1902, was submitted and approved.

The death of Professor A. H. Chester, of New Brunswick, U.S.A., an Ordinary Member of the Society, was announced.

Mr. Herbert Henry Thomas, B.A., F.G.S., of the Geological Survey, was elected an Ordinary Member of the Society.

Mr. Bowman, Mr. H. F. Collins, Dr. Cullis, and Mr. Solly were selected for nomination to replace the retiring Members of Council,

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namely, the Earl of Berkeley, Mr. J. H. Collins, Dr. Hutchinson, and Professor Lewis.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 9, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty Members and one Visitor were present. The election of Mr. H. H. Thomas to the Ordinary Membership of the Society was confirmed.

The Secretary read a statement relative to a proposal to place a memorial of the late Professor A. D'Achiardi in the Museum of Pisa.

The following papers were read:—

1. Notes on some mineral specimens from Santa Fé, State of Chiapas, Mexico: by Mr. H. F. Collins (p. 356).

2. Observations of the growth of crystals: by Professor H. A. Miers, F.R.S.

The new method of observation consists in tracing the changes of angle upon a crystal during its growth by measuring it at intervals by means of a specially devised inverted goniometer, without moving it from the solution in which it is growing. It was found that an octahedron of alum yielded invariably three images for each face, so that the crystal had really the form of a very flat triakis-octahedron. Similar observations on other crystals lead to the conclusion that the faces of a crystal are in general not faces with simple indices, but vicinal faces slightly inclined to them, which change their inclination during the growth of the crystal. By determinations of the refractive index of the solution by means of total reflection within the crystal, it was found that in each case the liquid in contact with the growing crystal is slightly supersaturated.

The former paper was illustrated by numerous specimens, and the latter by means of lantern slides.

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MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1902.

Receipts.	£ s. d.	£ s. d.
Balance from the year 1901		76 2 11
Subscriptions—(1) current	48 1 0	
(2) arrears	10 10 0	
		58 11 0
Entrance fees		8 8 0
Sale of publications by publishers to Dec. 31, 1901		37 7 0
Dividends on Stock		14 2 4
		£184 6 8

Payments.	£ s. d.	£ s. d.
Printing and Stationery (including Authors' copies, £5 1s. 8d.)		55 9 4
Illustrations		7 14 3
Editor's honorarium (1901)		10 10 0
Postage and Parcels		4 2 10
Attendant's Fee at Meetings		1 10 0
Binding	0 1 9	
Commission on P. O. Orders	0 0 8	
Banker's Commission	0 0 6	
		0 2 6
Investments and Brokers' Commission		14 2 4
Balance at Bank	88 6 10	
„ in Office	2 8 2	
		90 15 0
		£184 6 8

Examined and compared with the vouchers, and found correct.
April 30, 1903.

(*Signed*) J. H. COLLINS. H. L. BOWMAN. } Auditors.

Liabilities.	£ s. d.
Owing for Miscellaneous Printing	6 6 8
„ George Savigar for postage and care of Stock	1 9 1
„ Secretarial postage	0 5 11
„ Editor's Honorarium (1902)	10 10 0
Excess of assets over liabilities	604 19 4
	£623 10 7

Assets.	£ s. d.
Balance at Bank	88 6 10
„ in Office	2 8 2
Consols (£558 13s. 1d., valued at £91)	508 7 6
Balance owing from Publishers	11 11 6
„ „ „ Geo. Savigar for sale of publications	1 5 7
Subscriptions in arrear	11 11 0
	£623 10 7

The number of Life Members on December 31, 1902, was 52.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE,
Hon. Treasurer.

April 30, 1903.

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